THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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Telephone:- Grosvenor 4131

COMPARISON OF En STEELS WITH

A comparison of En Steels with other official specifications is provided in the following tables. others, it was felt advisable to include these for information purposes since they are still official specifications, based on chemical composition. They include also steels which, though

En No.	Type of Steel	UNITED KINGDOM				U.S.A.	
		B.S. Aircraft	D.T.D.	B.S. STA/5	B.S. General	S.A.E. and A.I.S.I.	A.M.S.
12	**DIRECT HARDENING** 1 per cent. Ni	(2S.76)	—	—	(5005/203) (5005/204)	—	—
13	Mn-Ni-Mo	—	510	V.8	—	—	—
21	3 per cent. Ni	—	—	—	(5005/401)	2330	—
22	3½ per cent. Ni	(S.69)	—	—	(5005/402)	2340	—
23	3 per cent. Ni-Cr	(4S.11)	—	—	(5005/501)	(3435)	—
24	1½ per cent. Ni-Cr-Mo ..	S.95	473 480	V.10	(5005/503) (b)	(3240) (b, c) 4340 (c)	6415B (c)
25	2½ per cent. Ni-Cr-Mo (medium carbon)	S.96 S.97	473 480	V.11	—	—	—
26	2½ per cent. Ni-Cr-Mo (high carbon)	S.98 S.99	473 500	V.12	—	—	—
27	3 per cent. Ni-Cr-Mo ..	(S.65) (2S.81)	—	—	—	(3325) (b)	—
28	3½ per cent. Ni-Cr-Mo ..	—	331	—	—	(3335) (b)	—
30A	4¼ per cent. Ni-Cr	—	—	V.13	(5005/502)	—	—
30B	4¼ per cent. Ni-Cr-Mo ..	3S.28	—	V.13A	—	—	—
100	Low Alloy	S.94	600	—	—	8640 (c)	—
100A	do.	—	—	—	—	8627 (c)	—
100B	do.	—	—	—	—	8632 (c) 8735 (c)	6280A (c, e) 6320B (c, d)
100C	do.	—	—	—	—	8637 (c) 8740 (c, d)	6322B (c, d)
100D	do.	—	—	—	—	8642 (c) 8742	—
110	Low Ni-Cr-Mo	—	—	—	—	4340 (c)	6415 B (c)
111	Low Ni-Cr	—	—	V9E or V9E1 (a)	—	3135	6330A
111A	do.	—	—	V9E or V9E1 (a)	—	3135	6330A
160	2 per cent. Ni-Mo	—	—	—	—	4640	6312A
160A	do. do.	—	—	—	—	4640	6312A

(a) Composition similar but with molybdenum added.
(b) Composition similar but without molybdenum.
(c) Possible alternative steel.
(d) Has higher carbon range.

OTHER OFFICIAL SPECIFICATIONS

Although from time to time some specifications have either been withdrawn or replaced by encountered in technical literature. The tables give the general relationship of all the various not similar in chemical composition, are possible alternatives.

En No.	Austria	Belgium	France	Germany D.I.N.	Italy U.N.I.	Sweden S.I.S. 14 Series
12	—	—	—	—	—	—
13	—	—	—	—	—	—
21	—	—	—	—	—	—
22	—	—	—	—	—	—
23	VCN 25w (g) VCN 35w (e) VCN 35h	Ni-Cr 322 (c, g)	30 NC 12	VCN 25w (g) VCN 35w (e) VCN 35h	32 NC 12	—
24	34 Cr-Ni-Mo 6 (e, f)	Ni-Cr-Mo 415	35 NC 6 (b, e)	34 Cr-Ni-Mo 6 (e, f)	40 NCD 7	25–32(c)
25	—	—	30 NC 11 (b)	—	—	—
26	—	—	—	—	—	—
27	—	Ni-Cr-Mo 335	30 NCD 12	—	30 NCD 12	25–34
28	—	—	35 NCD 14	—	35 NCD 15 (f)	—
30A	VCN 45 (d)	Ni-Cr 342	35 NC 15 (f) 40 NC 17 (d, f)	VCN 45 (d)	—	25–36
30B	—	Ni-Cr-Mo 342	30 NCD 16 (f) 40 NCD 18 (d, f)	—	35 NCD 15 (d, f)	—
100	—	—	—	—	—	—
100A	—	—	—	—	—	—
100B	—	—	35 NCD 4 (c)	36 Ni-Cr-Mo 3	—	—
100C	—	—	—	36 Ni-Cr-Mo 3	38 NCD 4	—
100D	—	—	—	—	—	—
110	34 Cr-Ni-Mo 6 (e, f)	—	35 NC 6 (b, e)	36 Cr-Ni-Mo 4 (g)	40 NCD 7	25–32 (c)
111	VCN 15w (e) VCN 15h	— —	35 NCD 4 (a) —	VCN 15w (e) VCN 15h	35 NC 5 (f)	25–30
111A	—	—	—	—	—	25–30
160	—	—	45 ND 10 (d)	—	—	—
160A	—	—	—	—	—	—

(e) Has lower carbon range.
(f) Has higher chromium range.
(g) Has lower nickel range.
( ) Not now official specification.

En No.	Type of Steel	UNITED KINGDOM				U.S.A.	
		B.S. Aircraft	D.T.D.	B.S. STA/5	B.S. General	S.A.E. and A.I.S.I.	A.M.S.
	CORROSION-RESISTING						
57	High Tensile Cr Ni	2S.80	—	V.28	—	51431 (c)	—
	CASE-HARDENING						
33	3 per cent. Ni	4S.15	—	V.17	(5005/103)	(2315) 2317 (d)	—
34	2 per cent. Ni-Mo (Lower carbon)	—	—	V.16A	—	4615 4617	6290C 6292C
35	do. (higher carbon) ..	—	—	V.16B V.16B/1 } V.16B/2 }	—	4620 (e) X4620 (e)	6294C (e) —
35A	do. do. ..	—	—	—	—	4620 (e) X4620 (e)	6294C (e)
35B	do. do. ..	—	—	—	—	—	—
36	3 per cent. Ni-Cr	S.107 (a)	519 (a)	V.18 V.18A	682	(3415)	—
37	5 per cent. Ni	(S.67)	—	—	(5005/104)	2512 2515	6240C
38	5 per cent. Ni	(S.90)	—	—	—	2515 4815 (c)	— —
39A	4¼ per cent. Ni-Cr	—	—	—	—	3316 (c)	6254E (c)
39B	4¼ per cent. Ni-Cr-Mo ..	2S.82	—	V.19	—	—	—
320	2 per cent. Ni-Cr-Mo ..	—	—	—	—	—	—
325	Low Ni-Cr-Mo	—	—	—	—	4320	—

(a) Composition similar but with molybdenum added.
(b) Composition similar but without molybdenum.
(c) Possible alternative steel.
(d) Has higher carbon range.

En No.	Austria	Belgium	France	Germany D.I.N.	Italy U.N.I.	Sweden S.I.S. 14 Series
57	—	—	Z 10 CN 17	X 22 Cr-Ni 17	X 20 NC 18	23–21
33	—	—	—	—	—	—
34	—	—	—	—	—	25–20–2 25–20–3
35	—	—	20 ND 6 (e, g)	—	—	—
35A	—	—	—	—	—	—
35B	—	—	—	—	—	—
36	ECN 35	Ni-Cr 235	14 NC 11 (g)	ECN 35	18 NC 13	25–14–2 25–14–3 25–15–2 25–15–3
37	—	—	Z 12 N 5	—	—	—
38	—	—	Z 20 N 5 (d)	—	—	—
39A	ECN 45	Ni-Cr 241	—	ECN 45	18 NC 16	—
39B	—	Ni-Cr-Mo 241	16 NCD 13 (f, g)	—	—	—
320	ECN Mo 40	—	—	18 Cr-Ni 8 (b)	—	—
325	—	—	16 NCD 4 (g)	—	17 NCD 7	—

(e) Has lower carbon range.
(f) Has higher chromium range.
(g) Has lower nickel range.
( ) Not now official specification.

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Identification Tests for Nickel-containing and Other Materials

INTERNATIONAL NICKEL CO., INC.: '(1) First Aids in Scrap Salvage.' '(2) Rapid Identification of Some Metals and Alloys.'* Published 1951.

The first of these bulletins describes some tests which can be easily made, with simple equipment, for identification of the following materials: nickel, Monel, Inconel, Incoloy, 70-30 cupro-nickel, and four types of stainless steel: Type 304 (unstabilized 18-8); Type 310 (20-25 nickel-chromium), Type 321 (titanium-stabilized 18-8), and Type 430 (straight-chromium steel containing 16 per cent. chromium). The tests described are qualitative only.

The second bulletin is a revised and amplified edition of an earlier publication. It is more comprehensive than (1), outlining procedures for identification of over 120 metals and alloys of nickel-containing and nickel-free types, by spot-test procedures. The typical chemical compositions of all the materials covered are listed in an appendix to the publication. Additional information of a reference type includes a *bibliography* of literature on identification tests, and directions for preparation of reagents required in spot testing.

Diffusion of Electrolytic Hydrogen Through Metals

See abstract on p. 59.

Production of Clad Metals

R. D. WEBER: 'The Cladding of Metals.' *Metallurgia*, 1952, vol. 45, Jan., pp. 3-6.

A brief discussion of the principles of metal cladding is followed by an outline of the various processes used for production of clad metals, with special reference to the techniques employed in solid-phase bonding. Liquid-phase cladding is also discussed and reference is made to manufacture of clad wire and tube. The final section of the review deals with recovery and use of scrap arising in production of clad materials. The article contains some drawings illustrating equipment and methods used in the respective processes described.

NICKEL

Adsorption of Carbon Dioxide on a Single Crystal of Nickel

A. D. CROWELL and H. E. FARNSWORTH: 'Adsorption of Carbon Dioxide on a Nickel Single Crystal Using a Radioactive Tracer.' *Jnl. Chemical Physics*, 1951, vol. 19, Sept., pp. 1206-7.

In previous experiments made to measure the amount of gas adsorbed on metal surfaces of known crystal orientation, chemisorption has been studied on evaporated metal films, and physical adsorption has been investigated on thin slices of a single crystal of copper. The present note gives results of preliminary attempts to measure the amount of gas chemisorbed on a single face of one single crystal of nickel. Comparative data were obtained on polycrystalline copper, nickel and silver. The radioactive tracer technique employed, using C^{14}, made it possible to determine the amount of carbon dioxide chemisorbed on metal surfaces having areas of 1-2 cm^2.

For the polycrystalline metals it was found that (1) carbon dioxide is irreversibly adsorbed on copper and nickel in observable quantities, (2) it is reversibly adsorbed on silver, and (3) observable amounts are absorbed in nickel if exposure occurs near 400°C. Measurable amounts of carbon dioxide were observed on the nickel single crystal, but the results were not reproducible.

Adsorption of Hydrogen on Nickel Catalysts

G. C. A. SCHUIT and N. H. DE BOER: 'Activated Adsorption of Hydrogen on Nickel Catalysts.' *Nature*, 1951, vol. 168, Dec. 15, pp. 1040-1.

After discussing conflicting conclusions which have been drawn by earlier investigators with regard to chemisorption of hydrogen on metals, the authors of this note briefly report experimental results which they consider to provide a full confirmation of the hypothesis advanced by ROBERTS that the oxygen content of a metal is responsible for activated adsorption (*Proc. Roy. Soc.* '*A*', 1935, vol. 152, pp. 445, 464, 477). The catalyst used in the work now reported consisted of 100 parts of nickel to 29 parts of silica (by weight), obtained by co-precipitation from nickel nitrate, sodium carbonate and sodium silicate solutions, and subsequent reduction. A fuller account of the work is to be published in Recueil des Travaux Chimiques des Pays-Bas.

Catalytic Activity of Nickel Produced by Reduction of Salts in Liquid Ammonia

G. W. WATT, W. F. ROPER and S. G. PARKER: 'The Catalytic Activity of Metals Produced by the Reduction of Salts in Liquid Ammonia. II. Nickel.' *Jnl. Amer. Chemical Soc.*, 1951, vol. 73, Dec., pp. 5791-3.

Studies on the preparation and properties of nickel hydrogenation catalysts formed by reduction of nickel (II) bromide with potassium in liquid ammonia show that the ammonia-insoluble reduction products include (in addition to elemental nickel and nickel amide) a potassium-containing substance which reacts with ethanol (the hydrogenation reaction medium) and with allyl alcohol (one of the hydrogen-acceptors employed), and that this substance influences both

* *We shall be pleased to supply a free copy of this publication.*

the rate and the mechanism of the hydrogenation of the latter.

Catalysts of the type described above were compared with W-6 Raney nickel, and with nickel obtained by the reduction of nickel (II) oxide with hydrogen; evaluation was made on the basis of surface area, adsorbed hydrogen and rate of the hydrogenation reaction.

Diffusion of Electrolytic Hydrogen through Metals

H. R. HEATH: 'An Experimental Investigation of the Diffusion of Electrolytic Hydrogen Through Metals.' *Brit. Jnl. Applied Physics*, 1952, vol. 3, Jan., pp. 13-18.

Report of experiments made to determine whether hydrogen produced electrolytically on one side of a metal plate will diffuse through the plate. The Shakespear katharometer was used to detect and measure the gas. The metals examined were iron, nickel, cobalt, copper, zinc, silver, palladium, platinum and lead: only in the cases of iron and palladium was any diffusion observed.

On iron, measurements were made to show variation of amount of diffused gas with time, and the influence of thickness of the plate on the rate of steady diffusion of the gas. Variation of rate of diffusion with electrolyzing current density was determined on plates of iron and palladium. The author compares his results with those of other investigators, and advances a simple theory to explain the general character of the experimental results obtained.

Constitution of Complex Organic Nickel Compounds

R. C. VOTER, C. V. BANKS, V. A. FASSEL and P. W. KEHRES: 'Nature of the Hydrogen Bond in 1, 2-Bis (*vic*-dioximo-*N*, *N'*) Nickel (II) Compounds.' *Analytical Chemistry*, 1951, vol. 23, Dec., pp. 1730-5.

Although the various *vic*-dioximes have been widely used in analytical chemistry of nickel and palladium, a more complete knowledge of the constitution of the inner-complex compounds thus formed is felt to be necessary for the extension of the scope of their application and the development of new organic analytical reagents.

It has long been assumed that the decreased reactivity of the remaining oxime hydrogens in the inner-complex compounds formed by the reaction of the *vic*-dioximes with nickel or palladium ions was caused by hydrogen bonding between these oxime hydrogens and the proximate oxygens of the nitrone-form oxime groups. In this paper, infra-red spectrophotometric evidence is presented to show that in the nickel inner-complex compounds of several *vic*-dioximes the characteristic absorption maxima normally attributed to O·H bonds are not detected in the usual region. These maxima, shifted slightly to lower frequencies because of intermolecular association, are noted in the spectra of the corresponding solid *vic*-dioximes. The conclusion is drawn that the oxime hydrogens of the metal derivatives are present in an O-H-O structure unlike that observed in normal hydrogen bonds.

B.S. Specification for Nickel-Clad Steel Plate

'British Standard Specification for Nickel-Clad Steel Plate.' *B.S.* 1822: 1952.

Covers steel plate to which a layer of nickel is integrally and continuously bonded, on one or both sides.

The base steel plate is to comply with the requirements for chemical composition specified in B.S. 1501-151, -154 or -157 (boiler-quality steels) and the cladding metal is to be of welding quality, complying with one of the schedules shown in the Table.

	Ni (incl. Co)	Cu	Fe	C	Mg	Ti
(1)	99·0 min.	0·25 max.	0·50 max.	0·10 max.	0·20 max.	0·10 max.
(2)	99·0 „	0·25 „	0·50 „	0·05 „	0·20 „	0·10 „

Composition (2) is for applications in which nickel with a specially low carbon content is desirable.

Tensile, surface-embrittlement and bend tests are laid down for the clad material, and permissible variations in thickness and weight of the composite plate and its component layers are specified.

Canadian Standard Specifications for Nickel and Nickel Alloys

See abstract on p. 62.

Magnetization of Nickel under Pressure

O. BUHL: 'The Magnetization Curve of Nickel under Tensile Stress.' *Zeitsch. für Naturforschung*, 1949, vol. 4, pp. 601-5.

The method introduced by Gerlach, of determining magnetization as a function of reduced magnetic field H/H_c, was used in tests on a nickel wire under various degrees of tensile stress.

Effect of Pressure on Electrical Resistance of Nickel

P. W. BRIDGMAN: 'The Electric Resistance to 30,000 kg./cm^2 of Twenty-Nine Metals and Intermetallic Compounds.' *Proc. Amer. Acad. Arts and Sciences*, 1951, vol. 79, Apr., pp. 149-79.

The work reported is a sequel to experiments made by the author thirteen years earlier, during which period additional refinements of measuring technique have been perfected and compressibility data on the

materials tested have also been obtained. Among the materials for which results are given is nickel: the measurements are stated to have been made on a sample of high purity. Anomalies observed in values for electrical resistance as a function of pressure are consistent with observations made on the compressibility characteristics of the metal.

Chloroform Extraction of Nickel (II) Salicylaldoximate

J. B. MARTIN and S. H. SIMONSEN: 'Chloroform Extraction of Copper (II) and Nickel (II) Salicylaldoximate.' *Analytical Chemistry*, 1951, vol. 23, Dec., p. 1892. Abstract of paper to American Chemical Society.

Report of quantitative extraction and evaluation of the extractability constants. Separation of copper (II) and nickel (II) and spectrophotometric determination of the copper tested on samples of National Bureau of Standards No. 85A wrought aluminium alloy containing 2·48 per cent. copper and 0·41 per cent. nickel.

Volatility and Stability of Nickel Sulphide

C. M. HSIAO and A. W. SCHLECHTEN: 'Volatility and Stability of Metallic Sulphides.' *Jnl. of Metals*, 1952, vol. 4, Jan. (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), pp. 65-9.

Results are given of determinations of the rate of weight loss of a number of metallic sulphides under very low pressures, at various temperatures. These data, correlated with observation and analyses of the products, reveal the mechanism of the weight loss which occurs, and also provide a basis for calculation of the vapour pressures or apparent vapour pressures of the sulphides. Some data on the non-volatile metallic sulphides are summarized in the table below. The following comments are made with regard to nickel sulphide (NiS):—

'The apparent vapour pressure is almost the same as the decomposition pressure reported by JELLINEK and ZAKOWSKI (*Zeitsch. anorg. Chem.*, 1925, vol. 142, p. 1). Chemical analyses indicate that the weight loss is at least 90 per cent. due to dissociation. HAYWARD (*Trans. Amer. Inst. Min. Met. Eng.*, 1914, vol. 48, p. 141) has reported that NiS readily loses sulphur upon heating until the residue attains the relatively stable composition of Ni_3S_2.'

Table I
Apparent Vapour Pressure-Temperature Relation for Certain Nonvolatile Metallic Sulphides

$$\text{Log } P_{mm} = -\frac{A}{T} + B$$

Sulphide	A	B	Temperature Range, °C.	Pressure Range, Log P_{mm}
MnS	11,937	4·633	904–1106	−5·79 to −4·32
FeS	10,850	4·162	804–1006	−5·84 to −4·26
CoS	12,630	6·751	804–1006	−4·99 to −3·13
NiS	9,213	5·84	604–804	−4·61 to −2·70
Cu_2S			604–904	−5·64 to −4·54
MoS_2	13,839	6·678	904–1106	−5·40 to −3·68

Young's Modulus of Nickel Oxide

R. STREET and B. LEWIS: 'Anomalous Variation of Young's Modulus of Antiferromagnetics at the Néel Point.' *Nature*, 1951, vol. 168, Dec. 15, pp. 1036-7.

Note reporting measurements of the variation of Young's modulus of nickel oxide and cobalt oxide, over ranges of temperature which included their respective Néel temperatures. (The Néel temperature of an antiferromagnetic is that below which antiparallel alignment of the spin vectors of the ions takes place.) The curves reproduced show large increases in the value of Young's modulus as the temperature of the specimens is increased through the Néel points. Two possible suggestions are advanced to explain this sudden change.

Polarographic Determination of Nickel in Copper-base Alloys

W. E. ALLSOPP and T. E. ARTHUR: 'Polarographic Determination of Nickel and Zinc in Copper-base Alloys.' *Analytical Chemistry*, 1951, vol. 23, Dec., pp. 1883-4.

Zinc and nickel are usually determined, in control analysis of copper-base alloys, by lengthy precipitations. Copper and lead are determined electrolytically after tin has been precipitated as metastannic acid.

This paper describes a method for polarographic estimation of zinc and nickel in the filtrate, after electrolytic separation and determination of copper and lead. Complete analysis of the sample, for copper, lead, tin, zinc and nickel can be carried out in three hours.

Determination of Nickel in Lithium

L. E. OWEN and J. Y. ELLENBURG: 'Spectrochemical Analysis of Lithium.' *Analytical Chemistry*, 1951, vol. 23, Dec., pp. 1823-5.

The paper describes a method developed at the Oak Ridge Laboratories of the N.E.P.A. project, arising out of investigations of the corrosion of metals and alloys by molten lithium. The procedure involved calls for spectrographic excitation, in a porous cup electrode, of the elements of analytical interest, separated from the lithium matrix. Analytical curves have been obtained for beryllium, chromium, cobalt, iron, nickel (given in the paper), niobium, manganese, molybdenum, titanium, uranium, vanadium and zirconium.

The procedure described is stated to have been employed in many laboratories, and to have formed the basis for the extension of this technique to determination of metallic contaminants in other alkali metals and their hydroxides.

ELECTRODEPOSITION AND OTHER COATING METHODS

Cleaning of Metals Prior to Electroplating: A.E.S. Research

H. B. LINFORD and E. B. SAUBESTRE: 'Cleaning and Preparation of Metals for Electroplating. IV. Degreasing Evaluation Tests: Sequential Testing.' *Plating*, 1952, vol. 39, Jan., pp. 55-63.

This instalment of the report contains appendices on variance analysis, statistical analysis of results, reproducibility of the sequential tests, sensitivity data, laboratory data, also a *bibliography* of 11 items additional to those given in an earlier instalment. For scope of the whole report see *Nickel Bulletin*, 1951, vol. 24, Nos. 9-10, p. 191; and 1952, vol. 25, No. 1, p. 8.

Electroplating and the Production of Chemical Finishes on Metals

H. SILMAN: 'Chemical and Electroplated Finishes. The Protective Treatment of Metals.' *2nd edn.: revised. Published by Chapman and Hall, Ltd., London*, 1952; 479 pp. Price 50/-.

The aim of the first edition of this book, published in 1947, was to assemble scattered data and to bridge the gap between text-books on applied electrochemistry and the literature of electroplating, providing the plater and the engineer with practical information on methods for the production of protective coatings and the properties of such coatings. These original objectives remain unchanged, and the new edition is designed to bring the subject matter into line with the rapid developments which have recently taken place in the plating industry. It gives a concise, but adequately detailed, summary of current views and the best types of practice in the industry. In addition to much information based on his own experience and on that of others in the British plating industry, the author has drawn extensively on the knowledge and practice in the U.S.A. References to the literature of that country are supplemented by unpublished information supplied by leaders in the American electroplating field.

Passing from an introductory discussion on the corrosion of metals and alloys, and the resulting need for protective finishes, the author discusses procedures for preparing metallic materials for the deposition of protective finishes (descaling and pickling; polishing, degreasing and cleaning). These chapters are followed by detailed consideration of methods of metal colouring.

Modern types of electroplating plant are next described, with illustrations of tanks, conveyors, and associated electrical equipment. Separate chapters are devoted to electrodeposition of individual metals and alloys: precious metals, nickel, chromium, copper and brass, tin and its alloys, cadmium, zinc, and lead. The chapter on nickel plating includes details of the composition and method of control of solutions used for deposition of matt or of bright nickel, on various types of base metal; the characteristics of the various types of anode now used; plating conditions, and the influence of the respective factors affecting the quality of deposit; the plating of zinc-base alloy diecastings; plating defects and their causes and remedies; impurities in nickel-plating solutions and their effects; filtration; bright nickel plating (including a table of the major patents governing the respective processes), and the mechanism of the brightening effect; British and American specifications for nickel plating. Special problems involved in the finishing of light alloys are reviewed and methods of overcoming them are described in detail. The final chapter is concerned with methods of test used to assess the quality of electroplated or other protective finishes: thickness, porosity, corrosion and adhesion tests are described; brief reference is also made to methods of determining hardness and wear-resistance.

Accelerated Corrosion Tests for Electrodeposited Coatings

'Report of Advisory Committee on Accelerated Corrosion Tests.' *Plating*, 1952, vol. 39, Jan., p. 65.

In February 1950 the American Electroplaters' Society organized an Advisory Committee to aid the Research Directing Committee in reaching a decision as how best to study the problem of developing satisfactory accelerated tests for the performance of plated coatings. The report now published embodies the recommendations of the Advisory Committee: the main features of these suggestions are summarized below:—

(1) The salt-spray (fog) test, as it is now employed, is not satisfactory and should be modified or replaced.

(2) It will be necessary to make a distinction between tests used for inspection and those devised to estimate performance in service: a single test is not likely to be suitable for both purposes nor for use with a variety of coating and basis-metal combinations.

(3) An inspection test should have a rational relationship to service requirements and performance.

(4) Bearing in mind the wide availability of salt-spray (fog) testing equipment, an endeavour should be made to develop an improved test which would permit of the use of this apparatus without restricting any new test to modifications of the current salt-spray test.

(5) With due regard to the foregoing limitations, it is recommended that the American Electroplaters' Society should sponsor a project to study accelerated corrosion tests. The type of test desirable is one which

(*a*) will disclose discontinuities in electrodeposited coatings,

(*b*) will create new discontinuities in a systematic way, at a rate which can be duplicated from test to test and which can be related to a widely representative practical environment.

Suggestions are made for the method of organizing and prosecuting the project, and, in closing, the report emphasizes the importance of supplementing the study of accelerated tests by the use of other test methods, and of correlation of all test data with behaviour under long-term exposure.

The A.E.S. Research Committee has accepted the

recommendations made, and Project No. 15, 'The Study of Accelerated Corrosion Tests' will be started as soon as a Project Committee is appointed.

Analysis of Plating Solutions: Textbook

K. E. LANGFORD: 'Analysis of Electroplating and Related Solutions.' *Published by Electroplating and Metal Finishing*, Teddington, Middlesex, 1951; 369 pp. Price 52/-.

The book is described as 'a collection of well tried and accurate methods, together with several original ones developed by the author or recommended by friends after very thorough investigation'. It is believed to be the first manual in which this type of information has been gathered together in ready-reference form.

An introductory chapter on sampling of solutions is followed by others containing details of methods recommended for analyses of solutions used in depositing various metals and alloys. The chapter on Nickel-plating Solutions deals fully with analysis of baths used in depositing dull, bright, and special-purpose nickel coatings, including the estimation of impurities in nickel-plating baths.

Later chapters cover analysis of alkaline cleaning solutions; etching, pickling, phosphatizing, dyeing and electrobrightening baths; identification of acids; analysis of plating salts, water and effluents.

General principles of the following methods, and their applications in the electroplating industry, are also discussed:—electro-analysis, conductiometric analysis, potentiometric titration, polarographic analysis, colorimetric methods, surface tension and swirl methods, and chromatographic analysis. The final chapter gives methods for preparation of standard solutions of chemicals which are in common use.

The information outlined above is supplemented by numerous tables of analytical data and other information likely to be of service to the analyst and plater. One of these tables comprises a list of substances in general use in the plating and allied industries, giving the names commonly used for the substances, the corresponding chemical names, and the appropriate formulae.

Electroformed Nickel Moulds

'Largest Electroformed Nickel Mold Produced.' *Nickel Topics*, 1952, vol. 5, No. 1, pp. 1, 5.

An electroformed nickel mould made for production of reinforced plastic aircraft radomes is believed to be the largest article ever made by this method. The mould is a split type, 14 ft. long by 8 ft. wide, and the electroformed nickel shell, only $\frac{1}{4}$-in. thick, is reinforced with steel ribbing welded to the outside surface, thus securing extremely light construction. Total weight of the completed mould is approximately 4,000 lb., i.e., only $\frac{1}{3}$ to $\frac{1}{5}$ that of a comparable cast-metal mould. Electroforming provides the most economical method of construction for such moulds, since it eliminates the necessity for the hand grinding and polishing which would be required to finish a cast-metal mould. The mould was electroformed in two halves, over plastic matrices, the time required for electrodeposition being 6-7 days.

Electrodeposited Tin-Nickel Alloy Coatings

K. ROSE: 'Electrodeposited Tin Alloy Coatings are Promising Alternates for Tin Plate.' *Materials and Methods*, 1951, vol. 34, Dec., pp. 70-2.

Review of some of the applications in which use can be made of tin-copper (45-55, Speculum), tin-zinc (80-20) and tin-nickel (65-35) deposits, to conserve tin. The tin-nickel plating (details of which were published by the Tin Research Institute in 1951 (*Nickel Bulletin*, 1951, vol. 24, Nos. 5 and 7, pp. 101 and 150), is characterized by good corrosion-resistance (especially under indoor conditions), hardness, high lustre, and a faint pinkish colour. Conditions of deposition, the advantages of the coating, and its scope of application, are briefly reviewed; the information given is based on papers which have been published by the originators of the process: see references above.

Stripping of Electrodeposited Coatings: Reference Data

R. H. KELLER: 'Stripping of Electrodeposits.' *Commonwealth of Australia, Dept. of Supply; Defence Research Laboratories, Information Circular No.* 16, Sept., 1951; 23 pp.

The publication contains, in readily accessible form, information culled from published sources on methods for stripping (from any of the metals on which they are usually deposited) coatings of brass, bronze, cadmium, chromium, copper, gold, lead, nickel, palladium, platinum, rhodium, silver, speculum, tin, and zinc.

NON-FERROUS ALLOYS

Canadian Standard Specifications for Nickel and Nickel Alloys

CANAD. STANDARDS ASSOCN.: 'HN Series Specifications for Nickel and Nickel Alloys.' *Published by the Association*, Nov., 1951.

The subjects of these specifications are shown below:—

HN-1 *General Specifications*, covering inspection and rejection, workmanship and finish, marking, and test procedures.

HN-2 *Standard Tolerances* for plate, sheet and strip; rods and bars; pipe and tubing.

HN-4 *Plate, Sheet and Strip*
- HN-4·1 Nickel (standard and low-carbon grades).
- 4·2 Nickel-Copper Alloy (Nickel 63-70 per cent.).
- 4·3 Nickel-Chromium-Iron Alloy (72 min./14-17/6-10 per cent.).

HN-5 *Rods and Bars*
- HN-5·1 Nickel (standard and low-carbon grades).
- 5·2 Nickel-Copper Alloy (nickel 63-70, standard and free-machining grades).
- 5·3 Nickel-Chromium-Iron Alloys (72 min./14-17/6-10 per cent.).

HN-7 *Pipe and Tubing*
- HN-7·1 Nickel Seamless Pipe and Tubing (standard and low-carbon grades).
- 7·2 Nickel-Copper Alloy Seamless Pipe and Tubing (Nickel 63-70 per cent.).
- 7·3 Nickel-Chromium-Iron Alloy Pipe and Tubing (72 min./14-17/6-10 per cent.).

7·4 Seamless Nickel and High-Nickel Alloy Condenser Evaporator and Heat-Exchanger Tubes (Standard and low-carbon nickel; 63-70 per cent. nickel-copper alloy; 72 min./14-17/6-10 per cent. nickel-chromium-iron alloy).

The requirements laid down in the materials specifications correspond closely to A.S.T.M. schedules for similar products: reference is given to the respective A.S.T.M. numbers.

Monel Stays in British Railways Standard Locomotives

'British Railways Standard Class '6' Locomotive.' *Railway Gazette*, 1952, vol. 96, Jan. 25, pp. 101-2.

Description, with scale-drawing, of the first locomotive of the Class '6' 4-6-2-mixed-traffic units, recently sent out from the Crewe works under the number 72000. It is noted, *inter alia*, that, in keeping with practice adopted in other types of standard locomotive recently built, all firebox waterspace stays are of Monel, fitted with steel nuts inside the firebox.

Monel Petrol Tanks

INTERNATIONAL NICKEL CO., INC.: 'Fabrication of Monel Tanks for Boats.' * *Published* 1952; 17 pp.

For some years past there has been increasing recognition of the peculiar suitability of Monel for fuel- and water-tanks in boats. Use of the alloy for this purpose ensures non-contamination of water, and freedom from clogging of fuel lines, or corrosion. It is anticipated that when current restrictions are removed, Monel tanks will be very widely used.

The publication now issued is designed to give all the particulars required to ensure easy and economical fabrication. Details are included on thickness of metal required for tanks of various sizes, welding materials and procedure, and inspection tests which should be applied to the tanks after fabrication.

Monel for Ball Valve Seats

See abstract on p. 84.

K Monel Drill Collars for Oil-Well Surveying

R. J. MAHAN: ' 'K' Monel Non-Magnetic Drill Collars for Oil-Well Surveying. *Amer. Petroleum Inst., Division of Production, Paper* 801-27*D*, May, 1951; with discussion; 11 pp.

The first practical investigation involving the use of non-magnetic sections in a drill string for surveying or orienting purposes was conducted about 1940. These early applications were concerned with providing a non-magnetic section in the drill string immediately above the bit, by means of which deflecting tools could be oriented.

Several types of material were investigated, including beryllium copper, austenitic stainless steel, and K Monel. The first two proved unsatisfactory, for reasons which are given in the paper, but K Monel met all the requirements and was considered eminently suitable for the purpose. Following these early tests, behaviour of K Monel collars was studied under service conditions, for a long period, during which various modifications of design were introduced. To-day over 31 different sizes and lengths of collar are supplied to meet the needs of the drilling industry, and they are employed in all types of oil-well surveying operations. The introduction of the K Monel collars is stated to mark 'the single greatest advance in the art in the last decade.' Their advantages are summarized by the present author as follows:—

'1. A 'Monel collar' provides a means for obtaining a highly accurate survey because the survey record is made in the centre of the bore hole free from the magnetic effect of the drill string.

'2. A 'Monel collar' reduces the hazard involved in surveying because the survey instrument is always used inside the drill pipe whether it is 'go-deviled' or lowered by a wire line. The danger of losing a wire line and instrument in the open hole due to key-seating, worn wire lines or sticking of the survey instruments is eliminated.

'3. A 'Monel collar' saves considerable rig time because the survey instrument may be placed in position in the 'Monel collar' with minimum effort. There is no lost time in spudding and 'pick-up'. An extra round trip of the sand line to pull the centre bit is not required. In fact a sand line need not be used at all if the instrument is 'go-deviled' and retrieved with the drill pipe.

'4. The cost of drilling operations is materially reduced with the use of the 'Monel collar' because faster surveys can be made, the proper type of bit for the job at hand can be used and, in general, the hole can be drilled faster.'

Discussion of the paper, by engineers representing prominent oil companies in California, confirmed the important advances which have resulted from the use of K Monel collars in surveying.

Iron-containing Cupro-Nickel Alloys: Constitution and Properties

E. W. PALMER and F. H. WILSON: 'Constitution and Properties of Some Iron-bearing Cupro-Nickels.' *Jnl. of Metals*, 1952, vol. 4, Jan. (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), pp. 55-64: T.P. 3203E.

Following the discovery of the beneficial influence of small amounts of iron in cupro-nickel alloys of the 70-30 type, various investigators have studied the properties of alloys of lower nickel content: see, for example, work reported by the British Non-Ferrous Metals Research Association (*Jnl. Inst. Metals*, 1951, vol. 79, pp. 243-92; *Nickel Bulletin*, 1951, vol. 24, No. 8, p. 185).

The present paper reports research carried out in the laboratories of the American Brass Company. It deals with the constitution of alloys in the copper-rich corner of the system, and with variations in hardness and tensile properties resulting from heat-treatment of alloys containing varying amounts of iron. Most of the information given relates to alloys containing 10 per cent. of nickel, which, when about 0·75 per cent. of iron is present, are subject to precipitation hardening. Typical effects producible by heat-treatment of alloys of various compositions are graphically illustrated. The consequences of this characteristic, in connexion with commercial production, are

* *We shall be pleased to supply a free copy of this publication.*

examined in some detail. Some data on cupro-nickels containing 2 or 5 per cent. nickel are also presented.

Constitutional studies showed that in cupro-nickel alloys of low nickel content the solid solubility of iron increases rapidly with rising temperature. For the 5 per cent. nickel alloy solubility of iron rises from about 0·2 per cent. at 500°C. to 0·95 per cent. at 750°C. For the 10 per cent. nickel alloy the rise is from less than 0·10 per cent. at 400°C. to 4·8 per cent. at 950°C.

The presence of iron above about 0·75 per cent. has a profound effect on the softening behaviour of the alloy and is a factor which calls for careful consideration in the development of these alloys for certain purposes. Whereas an iron-free 10 per cent. nickel alloy is completely softened, after cold-working, by 30 minutes' annealing at 500°C., a similar alloy containing 1·96 per cent. iron does not soften fully even after treatment at 800°C. It is pointed out that the precipitation-hardening properties are unimportant in the major applications of the alloys, which depend almost entirely on their corrosion-resistance. For the ends of condenser tubes which must be sufficiently soft to be rolled into tube sheets, and in salt-water lines which require bending, the precise properties required are most readily obtained by judicious adjustment of temper, rather than by utilizing precipitation-hardening capacity.

While maximum resistance to salt water impingement corrosion appears to be obtained in the 10 per cent. nickel alloys with a maximum amount of iron in solid solution, fabrication requirements limit the iron content to about 1·25 per cent., and it is considered that there are few, if any, applications in which the slight improvement in corrosion-resistance resulting from still higher iron contents justifies the much greater difficulty of fabrication involved by such modification.

As an addendum to their paper the authors call attention to the work of the British Non-Ferrous Metals Research Association (*loc. cit.*) with the results of which their own are in general agreement. They suggest reasons for the recommendations of somewhat higher iron content made by the British investigators.

Nickel in Bronze Alloys

D. HANSON and W. T. PELL-WALPOLE: 'Chill-Cast Tin Bronzes.' *Published by Edward Arnold and Co., London*, 1951; 368 pp. Price 75/-.

The aim of this book is 'to give a comprehensive metallurgy of bronze, with special reference to ingots and castings made in metal moulds.' Casting of shapes in sand moulds is not dealt with, but some of the chapters on melting, testing, etc., are of interest to producers of sand- as well as of chill-castings.

The general layout and scope of the book, with notes on the considerations which have dictated the line of treatment adopted, are indicated below:—

A history of bronze (Chapter I) has been included, because it is believed that the subject has not been treated in detail elsewhere. Chapter II, dealing with the methods used for assessing quality in cast bronzes, Chapter IV and a portion of Chapter V, on melting methods, and Chapter VIII, on chill-casting procedure, are written primarily for the practical foundryman, who will be closely interested also in tables and diagrams in later chapters referring to properties of the alloys.

Chapter III deals with the constitution of the binary copper-tin, the phosphorus-tin, zinc-tin, and lead-tin bronzes. It forms a comprehensive reference work on the subject.

Chapters V-VII are mainly concerned with modern research on melting and casting technique: the information given is based principally on work carried out by the authors and their colleagues in collaboration with the Tin Research Institute.

Chapters IX-XIII, on segregation, properties, influence of impurities, heat-treatment, and wrought bronzes, respectively, are also designed to form reference works on the individual aspects of the subject. In addition to a summary of published information, they contain results of some previously unpublished work, by the present authors.

The *bibliographies* given at the end of each chapter are extensive: the authors believe them to include all the most useful publications up to 1948, when the manuscript was completed. A brief list of the major publications since that date is given in an *additional bibliography* at the end of the book.

The effect of small percentages of nickel is summarized on pages 278-280: the influence of nickel in improving mechanical properties and refining grain size is illustrated, and reference is made to the use of nickel for minimizing lead segregation. The authors state that their results confirm that small amounts of nickel are beneficial in chill-cast bronzes, but that its effects are not so marked as in sand-cast bronzes.

Influence of Nickel on Grain Size of Copper-base Alloys

R. A. COLTON and M. MARGOLIS: 'Effects of Certain Elements on Grain Size of Cast Copper-base Alloys.' *Trans. Amer. Foundrymen's Assocn.*, 1951, vol. 59, pp. 360-8; disc., pp. 368-71.

The authors point out that there is a lack of clear-cut evidence on the effect of grain size on the properties of the copper-base alloys, and that this paucity of information is directly related to the absence of data on factors affecting grain size. Practical interest in the subject centres, in the foundry industry, primarily on the alloys used for cast products, and particularly on the 85-5-5-5, which is very generally used.

This paper reports study of the influence of nickel, up to about 2 per cent., on the grain size of the following types of alloys: copper + 5 per cent. lead; copper + 5 per cent. tin; copper + 5 per cent. zinc. By studying each of the binary alloys separately it was hoped to determine the magnitude of the individual influence exerted on grain size by each of the elements in the 85-5-5-5 alloy. Macrographs of alloys in the respective series are shown in the paper. Effect of cooling rate was eliminated by adoption of a uniform rate (35°F. per min.) for all the alloys investigated.

The observations made lead to the following conclusions:—

Composition of copper-base alloys influences grain size, but the effect is far less significant than that of

cooling rate. A high rate of cooling appears to be the best method for obtaining fine grain in cast alloys.

Five per cent. of lead markedly refines the grain of copper, and it is considered that lower lead contents may contribute to grain refinement of commercial copper-base casting alloys.

Nickel up to 2 per cent. in a 5 per cent. lead copper-lead alloy has a negligible effect on grain size.

Five per cent. of tin refines the grain of copper, but the effect is less pronounced than that of lead: nickel contents up to 0·10 per cent. have some grain-refining influence on copper alloys containing 5 per cent. of tin, but higher percentages of nickel appear to have no additional effect.

Five per cent. of zinc has a negligible influence on grain size of copper, and nickel up to 2 per cent. exerts no measurable effect on grain size of this type of alloy.

Nickel contents up to 0·10 per cent. refine the structure of a high-purity 85-5-5-5 copper-lead-tin-zinc alloy slightly, but with higher nickel the effect disappears and some coarsening occurs.

With a fast cooling rate (chill casting) high-purity 85-5-5-5 alloy containing 0·5 per cent. of nickel has a very slightly finer grain size than the same alloy without nickel, but the difference is very small.

Nickel contents up to 2·0 per cent. have no observable influence on shrinkage characteristics of any alloys studied, either at slow or fast rates of cooling.

Nickel contents up to 2·0 per cent. have no measurable effect on distribution and size of lead constituent in a 5 per cent. lead copper-lead alloy.

A cooling-rate curve at 35°F. min. shows that high-purity 85-5-5-5 alloy begins to freeze at 1835°F. (1002°C.).

Forging Tests on Copper-base Alloys containing Nickel

A. L. SIMMONS: 'Hot-Forging Tests on Some Copper-base Alloys.' *Australian Jnl. of Applied Science*, 1951, vol. 2, Mar., pp. 76-88.

Copper-base alloys are classified in three categories, according to the ease with which they can be hot-rolled:—

(1) *Easy to hot-roll*: copper; brasses containing up to 40 per cent. zinc, but excluding those containing 32-39 per cent. zinc; nickel silvers containing only low percentages of zinc (5 per cent. max.).

(2) *Requiring careful control in hot-rolling*: brasses containing about 32-39 per cent. zinc, e.g., 65-35 brass.

(3) *Not economically practicable for hot-rolling, due to excessive tendency to hot-cracking*: standard nickel silvers containing 60-65 per cent. copper, 10-25 per cent. nickel, balance zinc.

Various laboratory test methods have been proposed for evaluation of the large-scale hot-working properties of metals and alloys: these are reviewed by the author as a preliminary to a report of tests made, on a series of alpha copper-base alloys, to determine whether behaviour in the hot-upset forging test is a suitable criterion of hot-rolling properties.

Test apparatus (embodying a mild-steel anvil and hammer) and operating test conditions are described and illustrated. The materials subjected to test were: tough-pitch copper, cartridge brass, 65-35 brass, 10 and 20 per cent. nickel silvers to B.S. 970, 18 per cent. nickel silver (spring type), low-zinc 10 and 20 per cent. nickel silver and 70-30 cupro-nickel.

The results of the tests lead the author to the conclusion that the drop-hammer (hot-upset) test, under the conditions used in this particular investigation, does not provide an accurate criterion of susceptibility to cracking during hot-rolling. It is, however, believed that the test is of value in giving an idea of the *relative plasticity* of different alloys, when it is known that they can be hot-rolled. From this point of view the data obtained in the tests agreed with large-scale rolling experience.

Density of Nickel-Cobalt Alloys

M. YAMAMOTO: 'The Densities of Nickel-Cobalt Alloys.' *Science Reports, Research Inst., Tôhoku Univ., Ser. A*, 1950, vol. 2, Dec., pp. 871-7.

Reports of measurements, at room temperature, of the densities of 81 annealed nickel-cobalt alloys covering the entire range nickel to cobalt.

The results are discussed in relation to observations on the structure of the alloys in various portions of the system.

Nickel-Indium Alloys

E. HELLNER: 'The Nickel-Indium System.' *Zeitsch. für Metallkunde*, 1950, vol. 41, Nov., pp. 401-6.

Report of a detailed study of the system, using thermal, microscopic and X-ray methods. On the basis of the observations made, a complete phase diagram was constructed. A comprehensive summary of the conclusions drawn is given in *Metallurgical Abstracts*, 1952, vol. 19, Jan., p. 365.

Young's Modulus of Nickel-Manganese Alloys

T. FUKUROI and Y. SHIBUYA: 'Measurement of Young's Modulus of Metals and Alloys by an Interferometric Method. II. The Influence of Heat-Treatment on Young's Moduli and Densities of Nickel-Manganese Alloys.' *Science Reports, Research Inst., Tôhoku Univ.*, 1950, vol. 2, pp. 829-36.

In continuation of previous work on nickel-copper alloys (see *Nickel Bulletin*, 1951, vol. 24, No. 12, p. 255), the authors made a study of changes in Young's modulus and density of nickel-manganese alloys containing 1·43 to 23·8 per cent. manganese, heat-treated in various ways. For summary of results see *Metallurgical Abstracts*, 1952, vol. 19, Jan., p. 366.

Nickel-Osmium Alloys

W. KÖSTER and E. HORN: 'Study of the Systems of Osmium with Cobalt and Nickel.' *Heraeus Festschrift*, 1951, pp. 114-23.

Although alloys of osmium with cobalt or with nickel are in use for pen-nib tips, where their hardness and corrosion-resistance are especially valuable properties, no detailed study of the relation of composition and properties of such alloys has previously been published.

In the present paper results are given of determinations of the Curie points of the alloys, the temperature of the γ-ϵ transformation in cobalt-rich alloys, lattice parameters, and Vickers hardnesses. The main conclusions on the nickel-osmium series are given below:

Nickel and osmium form a simple heterogeneous series of alloys: nickel can dissolve about 15 per cent. osmium, osmium dissolves about 16 per cent. of nickel, both in solid solution. With rising temperature the solubility of osmium in nickel increases. Alloys containing 25 per cent. of osmium, when quenched from 1200°C. were homogeneous. The lattice parameter of nickel is increased by addition of osmium, but that of osmium is not affected by addition of nickel. The hardness of the alloys rises with increase in osmium content, the increase being at first relatively slow, but afterwards rising more rapidly, and attaining very high values in the region of 80 per cent. osmium.

In obtaining the powder required for X-ray examination it was found that alloys containing up to 50 per cent. osmium could be filed, and those containing somewhat higher percentages of osmium could be pulverized in a mortar, but at 75 per cent. osmium it was impossible either to file or pulverize. The alloys which could be filed were sufficiently plastic to be worked by hammer blow, but the higher-osmium alloys could not be so worked. Corrosion-resistance and general chemical stability increases with rising osmium content; alloys containing 77·5 per cent. osmium and upwards could be etched only by fused salts.

Proposed equilibrium diagrams for both systems are given in the paper.

Sigma in Nickel-Vanadium Alloys

W. B. PEARSON and J. W. CHRISTIAN: 'Sigma Phase in Vanadium-Nickel Alloys.' *Nature*, 1952, vol. 169, Jan. 12, pp. 70-1.

Preliminary note on observations made on single-crystal nickel-vanadium alloys containing 60 at. per cent. vanadium. A full account of the work is to be published elsewhere.

Identification Tests for Nickel-containing and Other Materials

See abstract on p. 58.

NICKEL-IRON ALLOYS

Equilibrium Diagrams of Iron-Nickel-Aluminium 'Permanent-Magnet' Alloys

O. S. IVANOV: 'Main Characteristics of Phase Equilibrium of High-Coercive Iron-Nickel-Aluminium Alloys.' *Doklady Akad. Nauk, U.S.S.R.*, 1951, vol. 78, pp. 1157-60: *Jnl. Iron and Steel Inst.*, 1951, vol. 169, Dec., p. 420.

'Phase diagrams based on: (1) dilatometric curves; (2) electrical-resistance/temperature curves; and (3) the physical properties and microstructure of an iron-nickel-aluminium alloy are given, and the main characteristics of the phase equilibrium are discussed.'

Irregularities in Magnetic and Electrical Properties of Nickel-Iron Alloys

I. EPELBOIN, A. MARAIS and D. DAUTREPPE: 'Methods of Study and Interpretation of Inhomogeneities in Ferromagnetic Materials in the Rayleigh Domain.' *Comptes Rendus*, 1950, vol. 231, pp. 222-4: *Metallurgical Abstracts*, 1952, vol. 19, Jan., p. 374.

Inhomogeneities in magnetic permeability and electrical conductivity in ribbons and wire of iron-silicon and iron-nickel alloys were revealed after repeated electrolytic polishing. Particular attention is directed to the occurrence, in an iron-nickel alloy of Permalloy type, of a superficial layer which shows a conductivity different from that characteristic of the rest of the specimen. This effect is thought to be due to diffusion of atoms, which sets up a difference in chemical composition, by a mechanism analogous to selective oxidation. In this connexion, the atmosphere in which heat-treatment is carried out is believed to play an important part.

Nickel-containing Permanent Magnets in Magnetic Chucks

'Magnetic Chucks Essential in Many Machining Operations.' *Nickel Topics*, 1952, vol. 5, No. 1, pp. 6-7.

Description of the design and operation of the range of chucks made by Brown and Sharpe Manufacturing Company, in which Alnico I or Alnico V permanent magnets are used.

Nickel-containing Materials in Hearing Aids

'Nickel Alloys a Boon to Hearing Aid Users.' *Nickel Topics*, 1952, vol. 5, No. 1, pp. 1, 7.

The article describes the operation of modern hearing aids, as exemplified by a Sonotone model. Due to recent improvements in magnetic materials, it is now possible to make these aids in very small size, while at the same time obtaining power many times superior to that obtained in earlier models. Among the materials which have contributed to such improvements are the permanent-magnet materials of the Alnico type, and the 50-50 nickel-iron alloys, which are used in the transformers. Contact springs in the Sonotone are of nickel silver or Duranickel.

CAST IRON

Structure and Properties of Acicular Cast Iron

E. A. LORIA: 'Structure and Mechanical Properties of a Mo-Ni-Cr Cast Iron.' *Trans. Amer. Foundrymen's Assocn.*, 1951, vol. 59, pp. 353-7; disc., pp. 357-9.

FLINN and REESE (1941 and 1942) showed that the as-cast strength of acicular nickel-molybdenum cast iron is increased by tempering at 500°-700°F. (260°-370°C.) for 5 hours or more. The present paper reports a study

of the structure and properties of an acicular iron as cast, in the customary 1·2-in. dia. bars, and after tempering for 5 hours at 400°, 600° and 700°F. (205°, 315° and 370°C.). The composition of the iron is given as total carbon 2·77, silicon 1·40, nickel 1·00, chromium 0·50, molybdenum 1·40, per cent.

The results of the tests confirm the beneficial effects, on mechanical properties, resulting from tempering in the range used. Much discussion took place on the nature of the structure, and on the author's method of describing it, particular objection being raised to the use of the term 'segregation' in relation to cast iron, which is known to freeze with a eutectic carbide structure assembling in a cell-like pattern: this is not correctly regarded as 'segregated'.

Spheroidal-Graphite Cast Iron: Properties and Nature of Potential Applications

M. BALLAY: 'Spheroidal-Graphite Cast Irons.' *Bull. Technique Bureau Véritas*, 1951, vol. 33, Dec., pp. 264-8.

The author points out that flake-graphite cast irons still have clearly defined limitations, in spite of the many improvements which have been effected in such materials by alloying, heat-treatment and other methods. In contrast, properties typical of spheroidal-graphite cast irons are reviewed.

It is stated that in France the present trend is towards production of three types: pearlitic, pearlitic/ferritic, and ferritic. Specifications for the three classes, now under consideration, are shown below:—

U.T.S.		Yield		Elongation
kg./mm²	t.s.i.	kg./mm²	t.s.i.	%
58	37	42	27	1·5-0·5
50	32	38	24	5
42	27	32	20	10

The paper includes reference to the more complex mechanical properties, and a general review of the foundry properties, machinability, frictional quality, resistance to wear, heat-resistance, physical characteristics, and weldability of spheroidal-graphite cast irons. A short section deals with heat-treatment, quoting some of the results presented by the author in his paper to the International Foundry Congress, 1951 (see *Nickel Bulletin*, 1951, vol. 24, No. 12, p. 257).

Established and potential applications of the new irons are considered in a classification dictated by the qualities required in materials for various types of service. It is pointed out that the irons can be regarded as:—

(1) Low-ductility materials, having mechanical strength much greater than that of normal cast iron, and improved shock-resistance.

(2) Materials having the ductility of blackheart malleable iron and steel, but stronger than the former and more wear-resistant than the latter.

(3) Primarily as materials having properties intermediate between those of the two preceding groups, for applications in which high strength, combined with an elongation of about 5-10 per cent., is desirable.

In accordance with this classification of the irons, established and potential applications are listed as shown below:—

(1) High-strength, low-ductility irons: for crank- and cam-shafts, gears, press frames, turbine casings, tyre moulds, and machine-tool parts.

(2) Pressure-tight castings, of improved mechanical strength: for pump- and compressor-bodies, valves, etc.

(3) High-strength pressure-tight castings: for parts which are of forms too complex to be cast in steel, e.g., compressor bodies, Diesel- and gas-engine cylinders and heads, forging-press cylinders, etc.

(4) Castings previously made in malleable, for applications in which a higher elastic limit is required, and for castings of which the dimensions are unsuitable for production in malleable iron.

(5) Parts such as shafts, where the machinability of spheroidal-graphite irons, as compared with that of steel, is an advantage, and for which the irons can be cast more closely to finished form.

(6) Heat-resisting castings: e.g., furnace doors, charger parts, burner bodies and tuyeres, in which ordinary cast iron fails rapidly, but for which it is not desired to use true heat-resisting alloys.

(7) Parts in which toughness is required, to resist accidental deformation, e.g., petrol- and water-pipes.

The article is well illustrated, showing many typical applications of spheroidal-graphite cast irons.

Fatigue Tests on Spheroidal-Graphite Cast Irons

T. F. EAGAN: 'Fatigue Strength of Nodular Iron Tested.' *Iron Age*, 1951, vol. 168, Dec. 13, pp. 136-9.

This paper covers results of work done by the author since the publication of a report on the notch-sensitivity of some cast materials (*Amer. Foundryman*, 1950, vol. 18, Nov., pp. 22-4).

Rotating-beam tests were made, on a Moore-type machine. It is pointed out that endurance-limit values obtained on any one material are influenced by the size of the test piece used: small test pieces give high results, but with test pieces of 1-in. diameter or above, the endurance-limit figure remains constant. For tests in which small specimens were used, the author therefore corrects his results to a 1-in. test piece, using an experimentally determined factor.

All the results quoted in the paper were obtained on material cut from the walls of actual castings: eleven nickel-magnesium-treated irons are represented, all being tested in both the as-cast and the annealed conditions. The endurance limits in the as-cast condition were 13-14 tons per sq. in., with a tensile strength of 38·5 tons per sq. in. For the annealed irons, endurance values of 10·7 and 11·8 tons per sq. in. were obtained, with tensile strengths of 32·5 and 35 tons per sq. in. respectively. Endurance ratio (endurance limit/tensile strength) for the whole range

of irons varied from 0·336 to 0·360. Use of a 0·05-in. radius notch was found to lower the endurance limit, in both as-cast and annealed irons.

Machinability of Cast Irons: Test Criteria

L. V. COLWELL, H. J. HOLMES and F. B. ROTE: 'A Comparison of Parameters for the Machining of Gray Cast Iron.' *Amer. Soc. Mechanical Engineers, Paper* 51-*A*-47, Nov., 1951; 9 pp.

The authors describe results of a research in which several forms of test data on typical cast irons were related to machinability, with a view to determining which of the properties could be correlated with cutting speed, and thus serve to provide a 'yardstick' of machining quality.

A series of eleven irons was examined: all were of the grey-iron type. Details of composition and microstructure given in the text show that four were of the plain-carbon or silicon type, with manganese, phosphorus and sulphur at approximately normal percentages, except for one higher-sulphur iron; two of the irons contained about 5 per cent. of ferrite, and two others (of higher silicon content) showed, respectively, 40 and 90 per cent. of ferrite. Typical examples of nickel, nickel-chromium and nickel-molybdenum cast irons were included, and other irons typified manganese-alloy, chromium-, and high-manganese, high-phosphorus nickel-chromium-molybdenum cast irons. Mechanical strength and hardness of all the irons are recorded.

In the machining tests, cutting force, power and energy were determined for each of the irons, from drilling and milling tests, and cutting-speed tool-life relationships were established. Finally, an attempt was made to correlate cutting speed for a 20-minute tool life with all other types of information on the irons.

Comparison on the reliability of the various forms of test data thus set up, in relation to machinability, showed that combined carbon, micro-hardness and the nucleating or graphitizing tendency of cast iron appear to offer the greatest possibility of providing useful criteria. Brinell hardness, tensile strength, drilling force and milling power show little promise of providing useful information. The results of the study are to be considered as preliminary only; the possible correlation established requires further exploration, confirmation, and development before it can be practically applied to determine machining quality.

Machining of Spheroidal-Graphite Cast Iron

K. J. TRIGGER, L. B. ZYLSTRA and B. T. CHAO: 'Tool Forces and Tool Chip Adhesion in the Machining of Nodular Cast Iron.' *Amer. Soc. Mechanical Engineers Paper* 51-*A*-39, Nov., 1951; 9 pp.

The paper opens with reference to investigations on machinability carried out by the Metcut Research Association, which indicated that, at appropriately equal hardness, as-cast spheroidal-graphite iron having a tensile strength of 93,000 p.s.i. (41·5 tons per sq. in.) has the same machinability as grey iron showing tensile strength of 45,000 p.s.i. (20 tons per sq. in.). The Metcut results further showed that annealed spheroidal-graphite iron of 70,000 p.s.i. (31·25 tons per sq. in.), showing a hardness of 170 Brinell, can be machined six times as fast, for the same tool life, as the strongest grey iron in the series tested.

The tests now reported were made to study performance of various grades of cemented carbide tools on spheroidal-graphite iron, in various conditions. Full details of test procedure are given, together with measurements of tool force, cutting speed, cutting temperature, etc. It is noted that with some of the grades of carbide build-up of metal occurs on the cutting edge when working on spheroidal-graphite iron: the effect is most clearly marked when the iron is in the annealed condition. The phenomenon is designated 'flank build-up'.

Welding of Spheroidal-Graphite Cast Iron

W. C. MEARNS: 'What You Should Know about Welding Ductile Iron.'* *Welding Engineer*, 1951, vol. 36, Nov., pp. 45-7.

Reprint issued by International Nickel Co., Inc., 1952.

Following a summary of the properties and characteristics of the main types of spheroidal-graphite cast iron now available, the author points out the advantages of such irons, in the ferritic condition, for water piping working under pressure. In pipes made in this material, if failure occurs, the pipe bursts, but does not shatter. A series of bursting tests on welded pipe is recorded, showing that the bursts occur through the wall of the pipe, not at the welds, and at pressures equal to those producing burst in unwelded piping of the same material.

Full details of arc-welding technique suitable for use on spheroidal-graphite cast iron piping are given. The recommendations cover welding of 8-in. and 12-in. piping, having wall thicknesses of $\frac{1}{4}$ in. to $\frac{1}{2}$ in. A Ni-Rod 55 type of electrode is used (nickel 60, iron 40, per cent.). A table of bursting pressures for standard unwelded and for as-welded piping is included, based on tests made by the Lynchburg Foundry.

Marine Applications of Spheroidal-Graphite Cast Iron

J. COURNOT: 'Recent Progress in Metallurgy.' *Bull. Technique Bureau Véritas*, 1951, vol. 33, Dec., pp. 227-33.

In this paper, which is a general review of high lights in recent metallurgical progress, the author draws attention, *inter alia*, to the advent of S.G. iron as one of the important developments of the past few years. Particular emphasis is laid on the interest of the new irons for marine applications, two examples of which are specifically mentioned:—

(1) The Compagnie Africaine d'Armement is now replacing steel tubing in a petroleum tanker by pipes in S.G. iron, 12-mm. wall thickness. This innovation effects a considerable reduction in weight, compared with piping in ordinary cast iron which has a wall thickness of 17-22 mm. Cast iron is preferred by some constructors as offering better resistance to corrosion than steel piping.

(2) Bureau Véritas has already included S.G. iron in its specifications, and rules for control and acceptance have already been established by the Bureau for S.G. iron porthole frames and covers, bearings, and stuffing-box glands.

* *We shall be pleased to supply a free copy of this publication.*

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Spheroidal-Graphite Cast Iron in the Automotive Industry

SOC. AUTOMOTIVE ENGINEERS, IRON AND STEEL TECHNICAL COMMITTEE: Section C, 'Report on Nodular Cast Iron.' *S.A.E. Jnl.*, 1951, vol. 59, Dec., pp. 23-4, 26.

This report is an attempt to evaluate the importance of nodular cast irons in relation to the requirements of the automotive industry. The assessment is based on comparison of the properties, costs and applications, in the industry, of nodular irons, and (1) ordinary grey cast irons, (2) malleable and pearlitic malleable irons, and (3) steel castings. Some of the conclusions drawn are given below:—

While the properties of nodular irons are far superior to those of *ordinary grey cast irons*, the latter are in most cases satisfactory for the purposes for which they are employed, and the costs of production and processing of nodular iron, vis-à-vis those for grey cast irons, would render substitution in most cases uneconomic.

At the present stage of development and cost, nodular irons are not likely to replace *malleable and pearlitic malleable irons* to any great extent in the automotive industry, but the economic production of malleable has certain section-size limitations, and in some branches of the industry there is use for castings of more than 2-in. section for which nodular iron might advantageously replace malleable. Progressive lowering of cost of production of nodular irons may be expected to make the position increasingly favourable to their use.

In comparison with *steel castings*, nodular iron appears to have a natural advantage in many applications, e.g., for components in which a material somewhat better than cast iron is desirable, but in which the properties of steel are not justifiably asked for. Costs of moulding, gating, risering, cleaning, and supervising for nodular iron might be presumed to compare favourably with those for steel castings, and machining costs, for comparable tensile and yield properties in the castings, are also lower for the irons than for steel. The excellent castability of nodular iron is a specially desirable feature for castings too complicated, or too variable in section, to be easily producible in steel.

The U.S. Defense Department is now using, for certain Service purposes, a nodular iron which meets the following specification: 95,000-105,000 p.s.i. (42·5-47 tons per sq. in.) tensile strength; 70,000-75,000 p.s.i. (31·25-33·5 tons per sq. in.) yield; 2·5-5·5 per cent. elongation; Brinell hardness 225-265. The American Society for Testing Materials has recommended two grades of nodular iron for consideration as Tentative Standards:—

Grade	80–60–03	60–45–10
U.T.S., min. ..	80,000 p.s.i. 36 t.s.i.	60,000 p.s.i. 27 t.s.i.
Yield, min. ..	60,000 p.s.i. 27 t.s.i.	45,000 p.s.i. 20 t.s.i.
Elongation, min.	3·0%	10·0%

CONSTRUCTIONAL STEELS

Cerium Additions to Carbon and Low-Alloy Steels, to Promote Ductility

C. D. BERRY: 'Effect of Cerium on Ductility and Impact Strength of Steel.' *Amer. Foundryman*, 1951, vol. 20, Dec., pp. 45-6.

The authors present experimental data demonstrating that addition of cerium plus aluminium, to carbon and low-alloy steel, gives mechanical properties superior to those obtained in corresponding steels in which aluminium or silicon alone is used as deoxidant. It is shown that cerium has a two-fold effect on sulphide inclusions in cast steel. First, it acts as a desulphurizer, and a second effect is that sulphide inclusions which do remain after such treatment are small, globular, and randomly distributed, due to being precipitated at an early stage in the solidification process.

Tests on carbon steel indicate that the cerium addition improves ductility at room temperature, and raises the sub-zero impact resistance. Additions of cerium to a steel having sufficient alloy elements to ensure a fully martensitic structure on water-quenching gave further proof of the beneficial effect of such treatment: see table below:—

Comparison of Impact Values of a Low-Alloy Steel with and without Mischmetall

Bar No.	Mischmetall lb./ton	Charpy V-Notch Impact Values, ft.-lb.					
		Room Temperature			−40°F. (−40°C.)		
780	0	42·0	44·0	43·0	40·0	38·5	39·0
780-1	4	63·5	58·0	61·0	56·0	53·0	55·0

Composition: Carbon 0·27, manganese 0·90, silicon 0·45, phosphorus 0·018, sulphur 0·031, chromium 0·56, nickel 0·70, molybdenum 0·53, per cent.
Addition of 4 lb./ton of Mischmetall reduced sulphur to 0·018 in bar 780-1.
Deoxidation: 2½ lb./ton aluminium.
Treatment: Water-quenched from 1600°F. (870°C.); tempered at 1150°F. (620°C.)
Hardness: 269 Brinell.

U.S. Steel Specifications

N. E. WOLDMAN: 'Steel Specifications.' *Iron Age*, 1952, vol. 169, Jan. 3, pp. 260-520 (broken pages).

Analysis of the groups of steel specifications shown below, correlated with a view to aiding defence contractors. In most cases the details given comprise designation of specification, composition, form of material covered, and similarity to other standard U.S. specifications.

S.A.E. Aeronautical Materials Specifications (A.M.S. series).
U.S. Air Force—Navy Aeronautical (A.N. series).
Alloy Casting Institute (A.C.I. series).
American Society for Testing Materials (A.S.T.M.).
U.S. Federal (Q.Q. series).
U.S. Military (MIL).
U.S. Army.
U.S. Navy.

Lean-Alloy and Boron-containing Steels in the U.S. Conservation Programme

'S.A.E. Steel Committee Leads Alloy Conservation Program.' *Iron Age*, 1951, vol. 168, Dec. 27, pp. 74-6.

The article reports progress in development of emergency steels made under the aegis of Division VIII S.A.E. Iron and Steel Technical Committee. At a meeting held in December, 1951, fourteen new grades were announced as standard A.I.S.I./S.A.E. steels (see Table below).

Five boron-containing steels (94B17, 14B50, 50B46, 86B45, and 14B35) have been formally accepted as H-band grades.

Research on the lean-alloy and boron-containing steels is being actively carried out by steelmakers and others: investigations include study of the susceptibility of the emergency steels to temper-brittleness, as compared with that of the earlier standard S.A.E. steels. It is reported that although boron-containing grades have been successfully applied for some purposes, the carburizing grades are still giving some trouble, mainly due to distortion, which is a serious limitation in their use for gears and some other purposes.

British Practice in the Use of Boron in Steel

W. E. BARDGETT: 'English Use Boron in Normalized and Drawn Heavy Sections.' *Iron Age*, 1952, vol. 169, Jan. 10, pp. 81-4.

This paper is based on work carried out by the United Steel Companies, Ltd., Sheffield, in which the advantage of boron additions in enhancing tensile and yield strengths in the as-rolled and the normalized conditions was demonstrated. A detailed account of this development was given in *Journal of the Iron and Steel Institute*, 1949, vol. 163, pp. 277-94; *Nickel Bulletin*, 1950, vol. 22, No. 1, p. 15.

Preferred Orientation in Nickel-Chromium and Ferritic Steel Castings

See abstract on p. 79.

New A.I.S.I. Alloy Steels

Grade	C %	Mn %	Si %	Ni %	Cr %	Mo %	Use
4118* Mod.	0·18-0·23	0·70-0·90		—	0·40-0·60	0·08-0·15	Ring gears
5155*	0·50-0·60	0·70-0·90		—	0·70-0·90	—	Springs
TS4613	0·10-0·15	0·45-0·65		1·65-2·00	—	0·25-0·35	Restricted to rock bit cutters
TS4618	0·15-0·20	0·45-0·65	0·20-0·35	1·65-2·00	—	0·25-0·35	Restricted to rock bit cutters
TS14B35†	0·33-0·38	0·75-1·00		—	—	—	Bolts
TS14B50†	0·48-0·53	0·75-1·00		—	—	—	Bolts
TS40B37†	0·35-0·40	0·70-0·90		—	—	0·08-0·15	Bolts, place type
TS43BV12**†	0·08-0·13	0·75-1·00	0·20-0·40	1·65-2·00	0·40-0·60	0·20-0·30	Aircraft
TS43BV14**†	0·10-0·15	0·45-0·65		1·65-2·00	0·40-0·60	0·08-0·15	Heavy duty trucks
TS46B12†	0·10-0·15	0·45-0·65		1·65-2·00	—	0·20-0·30	Rock bit cutters
TS50B50†	0·48-0·53	0·75-1·00		—	0·40-0·60	—	Truck axles
TS50B60†	0·55-0·65	0·75-1·00	0·20-0·35	—	0·40-0·60	—	Springs
TS80B37†	0·35-0·40	0·75-1·00		0·20-0·40	0·20-0·35	0·08-0·15	Bolts, over $\frac{9}{16}$-in.
TS81B40†	0·38-0·43	0·75-1·00		0·20-0·40	0·35-0·55	0·08-0·15	Steering knuckles and axles

* New standard steel. ** Contains 0·03% V, min. † Can be expected to contain 0·0005% B, min.

Weldable Complex Nickel-Copper-containing Steels for Pressure Vessels

F. NEHL: 'Weldable Low-Alloy Steels of High Yield at Elevated Temperature, for Pressure Vessels.' *Stahl und Eisen*, 1951, vol. 71, Dec. 20, pp. 1443-4.

After a condensed review of considerations involved in selection of compositions of steels suitable for welded pressure vessels, the author advocates the use of low-alloy copper-nickel-molybdenum types, giving results of tests made on two typical steels of the composition shown below.

Table I.

Steel	C	Si	Mn	Cr	Cu	Mo	Ni	(Ta+Nb)
A	0·14	0·35	1·0	0·10	0·85	0·24	0·74	—
B	0·15	0·43	0·96	0·30	0·98	0·22	0·79	0·013

The properties in Table II are reported as averages obtained from a number of tests:—

The author states that long-time creep tests (10,000 hours' duration) showed no fall in yield at test temperature, nor rise in tensile-strength values. The fall in impact strength is within the limits recognized as associated with blue brittleness occurring on heating at 350°C. A series of pressure vessels has already been made from steels of the above composition: welds were made with shielded arc, using electrodes of copper-nickel-molybdenum steel containing additions of niobium. By using two electrodes 170 mm. apart it was found possible to prevent cracking. The author emphasizes the significance of such steels for production of pressure vessels.

Table II.

Temperature °C.	Steel	Heat-Treatment†		Yield	U.T.S.	Yield at Temperature of Test / U.T.S. at 20°C.	Elongation	R. of A.
		Normalized °C.	Final Heat Treatment °C.	kg./mm²	kg./mm²	%	%	%
20	A	880	—	42·6	63·1	68	25·5	68
	B		—	52·0	90·4	57	11·3	20
	A		625*	39·8	55·6	72	25·0	65
	B		625*	52·9	67·8	78	20·6	59
350	A	880	—	30·2	63·9	47	24·5	47
	B		—	48·5	88·6	54	15·0	26
	A		625*	30·3	54·7	55	25·2	55
	B		625*	45·5	64·0	67	20·3	48

† Cooled at 7°C. per min. * Heated for 8 hours.

Design Data for High-Temperature Pressure-Vessel Materials

See abstract on p. 75.

Bolts, Studs and Nuts for Use in the Petroleum Industry

BRIT. STANDARDS ASSOCN.: 'Bolting for the Petroleum Industry.' *B.S.* 1750: 1951.

Part 1. *Alloy Steel Stud-Bolts, Studs, Bolts and Screws for High-Pressure and High-Temperature Service*

The steels specified, covered by B.S. 1506, are of the following types: chromium-molybdenum (containing, respectively, 1 per cent. chromium with ¼ or ¾ per cent. molybdenum and 5 per cent. chromium with 0·45-0·65 per cent. molybdenum); 1 per cent. chromium, containing molybdenum and vanadium; 13 per cent. chromium, and 18-8 chromium-nickel.

Mechanical properties for the steels in various limiting sections, and heat-treatment temperatures, are specified. Design, marking, testing, and inspection of the respective components are covered.

Part 2. *Carbon and Alloy Steel Nuts for High-Pressure and High-Temperature Service*

This specification includes 45-ton carbon, 5 per cent. chromium-molybdenum, carbon-molybdenum, 13 per cent. chromium, and 18-8 chromium-nickel steels. It covers composition, manufacture and heat-treatment, dimensions, finish, marking, testing, and inspection.

Part 3. *Carbon Steel Bolts, Stud-Bolts, Studs and Nuts for Moderate Duty Service*

The bolting covered by this specification is intended for pressures not exceeding 250 p.s.i. and temperatures not exceeding 450°F. (232°C.). It is not recommended for sub-zero service for applications in which

embrittlement would create a hazard. Composition of carbon steels, treatment and properties are covered, with details of design, manufacture, testing and inspection of the components.

In view of the international character of the petroleum industry, Parts 1 and 3 have been drawn up to give components equivalent in service to certain grades of bolting and nuts covered by A.S.T.M. specifications.

Appendices to the specifications include a table showing maximum allowable design stresses in tension for materials mentioned in Part 1. The figures given correspond to those given in the A.P.I.-A.S.M.E. Code for unfired pressure vessels for petroleum, liquids and gases for similar bolting materials, and are appropriate for use with the design procedure laid down in that Code.

Determination of Manganese in Iron and Steel

BRIT. STANDARDS INSTN.: 'Methods for the Analysis of Iron and Steel: Manganese in Iron and Steel (Absorptiometric Method).' *B.S.* 1121: Part 23: 1951.

In the method described, which is recommended as a referee procedure, the sample is dissolved by treatment with phosphoric-sulphuric and nitric acid, the manganese is converted to the permanganic state by boiling with potassium periodate, and the determination is finished absorptiometrically.

The range of manganese content to which the method is applicable is up to 2 per cent. Reproducibility obtainable:—

With 0·2 g. sample and a 1 cm. cell
±0·02 per cent. manganese.
With larger cells the reproducibility is improved.

The method has been applied satisfactorily over a wide range of steels: for carbon and low-alloy types a reproducibility better than that claimed may be expected. Full details of procedure are given, including steps specifically directed towards facilitating the use of the method on higher-alloy steels, e.g., those of high nickel content.

Dissimilar-Metal Welded Joints made with Stainless-Steel Electrodes

See abstract on p. 87.

HEAT- AND CORROSION-RESISTING ALLOYS

High-Temperature Properties of Metallic Materials: A.S.M. Lectures

AMER. SOC. METALS: 'High Temperature Properties of Metals.' *Published by the Society*, 1951; 176 pp.

This volume contains reprints of five educational lectures delivered during the 32nd National Metal Congress and Exposition, Chicago, 1950. The broad outline of the individual lectures is briefly as below:—

E. R. PARKER: 'Creep of Metals.' pp. 1-40.

Discussion of the phenomenon of creep, supported by an extensive *bibliography* of the major literature (84 references). The aspects of the subject treated include mechanisms of deformation and effects occurring in the primary, secondary and tertiary stages of creep; theories of creep; creep properties of various metals and alloys (briefly treated, with additional references to sources of fuller information); effect of environment on high-temperature properties; current trends in the development of creep-resistant materials.

N. J. GRANT: 'Stress Rupture Testing,' pp. 41-72.

The nature of the stress-rupture test is described and its advantages are urged, with discussion of the type of information which it supplies, and the factors which affect the stress-rupture properties of metallic materials. *Bibliography* 24 references.

H. J. GROVER and H. C. CROSS: 'High Temperature Fatigue Testing,' pp. 73-92.

Introductory note on the importance of fatigue-resistance as affecting serviceability of materials under high-temperature conditions, e.g., in gas turbines, followed by detailed discussion of factors important in high-temperature fatigue testing, test methods used, and the bearing of the results on design and service behaviour.

C. WAGNER: 'Methods of High Temperature Oxidation Testing and Evaluation of Observations,' pp. 93-132.

The paper opens with a review of experimental methods used for kinetic investigations (weighing, gas-pressure, and gas-volumetric methods, electrochemical measurements, determination of consumption of metal, optical methods, microscopical determination of the thickness of an oxide layer, determination of the weight of stripped oxide films). This is followed by brief notes on methods employed for determination of the structure of oxide layers, and detailed discussion of rate laws for the oxidation of metals. Consideration is then given to the dependence of the reaction rate on the concentration of the oxidizing agent and the dependence of rate of oxidation on temperature. It is admitted that certain peculiarities involved in the oxidation of alloys are not yet fully understood, but some of the salient features of the phenomena on which information is already available are illustrated by discussion of relatively simple cases which display typical features. Among the cases so considered are the oxidation phenomena occurring in nickel-platinum, nickel-copper, nickel-chromium, nickel-manganese, and other binary and complex nickel-containing materials. The final section of the lecture dealt with the formation of gaseous reaction products. A *bibliography* of 89 references is appended.

J. J. B. RUTHERFORD: 'Some Experiences in Service (Power, Oil and Chemical Plants),' pp. 133-70.

This lecture described some typical cases of service behaviour of components, the design of which had been based on test results obtained by some of the methods described in the earlier lectures. Although the majority of cases discussed consist of failed parts which had been received for examination, it is emphasized that these should be regarded as the abnormalities

rather than as typical. The series therefore opened with notes on a more representative example, that of a product which had been removed for examination after long service in which no failure had occurred (a cracking-still tube of chromium-molybdenum steel). Examples of unusual behaviour referred to include carbide precipitation in 18-8 stainless-steel pipe line after service at 950°F. (510°C.); intergranular oxidation in 25-20 nickel-chromium and in carbon steels; carburization in straight-chromium steels; attack of salts at high temperatures on chromium steels; pitting corrosion of 18-8 chromium-nickel steel from salts in naphtha; intergranular corrosion of 25-20 stainless steel caused by sulphur; attack of 25-20 steel by vanadium pentoxide; various forms of embrittlement and of excessive scaling; failures resulting from thermal fatigue and from corrosion fatigue; failures due to manufacturing defects in the materials, or to excessive stresses, thermal and mechanical.

Inter-Relation of Static and Fatigue Properties of Alloys at High Temperatures

NAT. ADVISORY COMMITTEE FOR AERONAUTICS: 'Co-operative Investigation of Relationship between Static and Fatigue Properties of Heat-Resistant Alloys at Elevated Temperatures.' *N.A.C.A Research Memorandum* 51*A*O4, Mar. 7, 1951; 51 pp.

This is an interim report of work in an investigation of the relation between static and dynamic properties, which is in progress with the two-fold object of (1) determining the relationships in individual heat-resisting alloys, and (2) providing a more reliable basis for evaluating results of tests on various types of fatigue-testing machine.

The tests now reported were made on the low-carbon grade of alloy N-155: reasons for selection of this material are detailed in the report. Data from static tensile and rupture tests, combined dynamic and static stress tests, and completely-reversed stress fatigue tests are reported, covering properties at room temperature, and 1000°, 1200°, 1350° and 1500°F. (538°, 648°, 734° and 815°C.). The results are summarized as curves of alternating stress against mean stress, for fracture in 50, 150 and 500 hours. Some creep data under combined-stress conditions, and a summary of the fracture characteristics of the specimens in the various tests, are also included.

Organisations co-operating in the full series of investigations include U.S. aeronautical and naval research laboratories, and representative firms engaged in high-temperature metallurgical and engineering activities, and a British firm concerned with high-temperature work in the gas-turbine field.

Influence of Combined Stress on Creep of N-155 Alloy

C. W. MACGREGOR and F. J. WALCOT: 'Investigation of Torsion Creep-to-Rupture Properties of N-155 Alloy.' *Nat. Advisory Committee for Aeronautics, Research Memorandum R.M.*51 *EO*4, Aug. 21, 1951; 26 pp.

Although the effect of combined stresses on creep has already been the subject of some study, there is a sparsity of data on their influence on creep-to-rupture properties. The practical importance of the subject is apparent from the fact that combined stresses are present in most machine components in which creep-to-rupture properties are important. Information is lacking also on the influence, on creep-to-rupture properties, of stress concentration, which is usually present in varying degrees.

The investigation which is the subject of this report was undertaken to supply some practically useful data on the properties of a material which is of importance in gas-turbine design. The study was mainly limited to torsion-creep tests; full details are given of the testing machine and technique, and the relationship between tension- and torsion-creep curves is discussed.

In the tests on N-155 alloy rupture times in the 10-to-1000-hour range were considered, and the test temperatures were 1200°, 1350° and 1500°F. (648°, 734° and 815°C.). The effect of stress-concentration, produced by transverse circular holes, was investigated under the same conditions. Comparisons of the effects of simple combined stresses (as in torsion) were made with tension creep-to-rupture properties.

It was found that the ratio of the shear stress to tensile stress for a given time to rupture was about 0·74 for both long- and short-time tests at 1200° and 1350°F. (648° and 734°C.), but varied from this figure to about 0·65 for the short-time tests at 1500°F. (815°C.). The effect of the stress concentration produced by circular holes was to reduce the time to rupture at 1200°F. (648°C.) by a factor of 25; at 1500°F. (815°C.) this factor was approximately 3.

Influence of Composition on High-Temperature Strength of Low-Carbon N-155 Alloy

E. E. REYNOLDS, J. W. FREEMAN and A. E. WHITE: 'Investigation of Influence of Chemical Composition on Forged Modified Low-Carbon N-155 Alloys in Solution-treated and Aged Condition, as Related to Rupture Properties at 1200°F.' *Nat. Advisory Committee for Aeronautics, Tech. Note* 2449, Sept., 1951; 111 pp.

The basis composition of the alloy studied is given as carbon 0·15, manganese 1·7, silicon 0·5, chromium 20, nickel 20, cobalt 20, molybdenum 3, tungsten 2, niobium 1, nitrogen 0·12, iron 32, per cent. The influence of composition was evaluated on 62 modifications of this alloy, within the following ranges:—

(1) Individual variations of the elements in the basic composition:—

	Per cent.
Carbon	0·08, 0·40, 0·60
Manganese	0·03, 0·25, 0·5, 1·0, 2·5
Silicon	1·2, 1·6
Chromium	10, 30
Nickel	0, 10, 30
Cobalt	0, 10, 30
Molybdenum	0, 1, 2·3, 5, 7
Tungsten	0, 1, 5, 7
Columbium	0, 2, 4, 6
Nitrogen	0·004, 0·08, 0·18

(2) Simultaneous variations, in steps of 2 per cent., of molybdenum, tungsten and niobium, from 0 to 4 per cent.

In all cases, iron variation compensated for changes in total-alloy content.

The alloys were melted as 9-lb. induction-furnace heats, the ingots were hot-forged to bar stock, and this was treated by heating at 2200°F. (1204°C.), for one hour and water-quenching, followed by ageing at 1400°F. (760°C.) for 24 hours.

Metallographic examination was made of all the alloys in the as-cast, hot-forged, solution-treated, aged, and rupture-tested conditions. Vickers hardness tests were made on bar stock in the solution-treated and aged conditions.

Load-carrying ability was evaluated by means of stress-rupture tests at 1200°F. (648°C.). At least two, and usually three or four, tests were made at various stresses, on each alloy, and the tests were of sufficiently long duration to establish the 100-hour rupture strengths and to permit an estimate of the 1000-hour strengths. The 100-hour rupture values varied over the range 26,000 to 52,000 p.s.i. (11·6 to 23·2 tons per sq. in.) according to composition and condition. Major strengthening effects were found to result from additions of molybdenum, tungsten and niobium, both when added individually or in combination: the lowest-strength alloy contained none of these addition elements. Chromium also had a markedly strengthening influence, but none of the modified alloys showed properties outstandingly superior to those of the standard low-carbon N-155 alloy of the basis composition.

With regard to the effects of the individual elements present in the basic composition, the following conclusions are drawn: Carbon (0·08-0·6)*, nitrogen (0·08-0·18), manganese (0·3-2·6), nickel (11-20), cobalt (20-33), and niobium (2-4) had little influence on rupture properties. Nitrogen (0·004-0·08), chromium (10-30), nickel (0-11), cobalt (0-20), molybdenum (0-4), tungsten (0-4), and niobium (0-1) appreciably increased the strength of the alloys. Silicon (0·5-1·6) and nickel (20-30) had a weakening influence. Niobium exerted a specially marked influence in increasing total elongation to fracture.

Effect of Cold Work on Creep of Low-Carbon N-155 Alloy

D. N. FREY, J. W. FREEMAN and A. E. WHITE: 'Fundamental Effects of Cold-Working on Creep Properties of Low-Carbon N-155 Alloy.' *Nat. Advisory Committee for Aeronautics, Tech. Note* 2472, Oct., 1951; 45 pp.

This report covers part of an investigation into the fundamental behaviour, at high temperature, of austenitic alloys designed for use in aircraft propulsion systems. Earlier N.A.C.A. reports and other papers have dealt with the effects of ageing on low-carbon N-155 and Inconel 'X' and with the influence of chemical composition of N-155 (see preceding abstract).

The investigation was carried out with the dual purpose of ascertaining the reasons for the improvement in the creep-resistance of N-155 found to result from cold-working, and elucidating the conditions under which cold-working may be expected to confer such improved high-temperature properties. (Cold-working is taken to signify any working carried out below the temperature at which recrystallization occurs during the rolling operation.)

Effects of cold-working under various conditions were evaluated by creep tests at 1200°F. (648°C.), and by determination of the influence of such working on the internal structure of the material. In addition, the effects of annealing, at various temperatures and for various times, on creep-resistance and structure of cold-worked samples, were studied.

The observations made are interpreted as showing that the improved creep properties conferred by cold-working are brought about by the introduction of residual elastic stresses into the lattice, such stresses acting to prevent movement of the fundamental creep flow units. In accordance with this finding, an optimum amount of cold-rolling exists for improvement of creep-resistance at any given temperature, and amounts of reduction past this critical maximum produce an internal configuration which allows internal-stress relaxation to occur to a significant extent during service of the material at high temperature. Conversely, for any given degree of cold reduction, such working may be expected to improve creep-resistance only at service temperatures below those which permit internal-stress relaxation to occur in significant amounts during service or test. Moreover, cold-rolling must be performed at temperatures below a critical value, in order to prevent stress relaxation during the rolling operation or during cooling-down after rolling. Attention is directed to the fact that this relaxation of internal stress, the occurrence of which nullifies the improvement of creep properties conferred by cold-working, is a recovery process occurring at shorter time-periods and/or lower temperatures than recrystallization.

Although it is considered that these findings must be generally applied only with caution, it is believed that by the use of a 'standardizing' solution treatment prior to the cold-working operations the results of the tests can probably be safely applied to other commercial heats of low-carbon N-155 bar stock, since there is a growing body of evidence indicating that the effects observed are general in alloys of the N-155 type. The findings are not applicable to alloys exhibiting pronounced improvement in creep-resistance by virtue of precipitation, e.g., Inconel 'X'.

Influence of Tantalum on High-Temperature Strength of Low-Carbon N-155 Alloy

J. W. FREEMAN, E. E. REYNOLDS and A. E. WHITE: 'Rupture Properties of Low-Carbon N-155 Type Alloys made with a Columbium-Tantalum Ferro-Alloy.' *Nat. Advisory Committee for Aeronautics, Tech. Note* 2469, Oct., 1951; 11 pp.

In the interests of conservation of niobium, and with a view to ascertaining the practical utility of niobium-tantalum ferro-alloys as addition materials in high-temperature alloys, properties were determined on a laboratory-made low-carbon N-155 alloy containing molybdenum and tungsten, and on a type of N-155 alloy containing neither molybdenum nor tungsten,

* Figures shown in brackets are percentages.

in both of which a ferro-alloy having a tantalum: niobium ratio of 0·55 was used. The amount of niobium in the alloys was reduced so as to keep the atomic percentage of niobium-tantalum equal to the atomic percentage of niobium normally present.

Rupture tests at 1200° and 1500°F. (648° and 815°C.), on forged and heat-treated bar stock, showed no significant change resulting from the use of the tantalum-containing ferro-alloy. The conclusion is therefore drawn that such material could be used to effect saving in niobium.

Design Data for High-Temperature Pressure-Vessel Materials

R. D. WYLIE and H. THIELSCH: 'Creep and Stress-to-Rupture Properties of Pressure Vessel Steels.' *Welding Jnl.*, 1952, vol. 31, Jan., Suppl., pp. 11-19.

This article is designed to serve as 'an interpretive engineering statement of the latest knowledge on the creep and stress-to-rupture characteristics of pressure-vessel materials'.

It opens with a note on definitions of high-temperature long-time properties, and with a review of the nature of the tests used to determine such properties, and the extent to which results obtained from them can be used to assess probable service behaviour. Typical creep and stress-rupture diagrams are shown to illustrate effects produced at various stages of testing.

The second section of the paper reviews factors affecting creep strength: (1) chemical composition; (2) structure and grain size, which are controlled primarily by prior processing and heat-treatment; and (3) structural stability at the temperature of test or service. The importance of constancy of temperature in testing is emphasized, as affecting creep and stress-to-rupture properties, and attention is called to the considerable variations in behaviour which may be caused in service by cyclic temperature effects.

The authors then give tables taken from the 1950 Boiler Construction Code drawn up by the American Society of Mechanical Engineers. These relate to:—

(1) Maximum Allowable Stress Values in Tension for Carbon and Low-Alloy Steel Plates (including data for nickel steel).

(2) Maximum Allowable Stress Values in Tension for Carbon and Low-Alloy Steel Pipes and Tubes.

(3) Maximum Allowable Stress Values for High-Alloy Plate Materials (high-chromium and chromium-nickel steels).

In determination of stress values the A.S.M.E. Committee on Stress Allowances has in many cases been guided by successful service experience with the respective steels, but in evaluation of new materials comparison of test data with service record of established materials is necessary, and the Committee has, in the course of this work, developed certain criteria which are being applied, in association with other available data, in developing design requirements. The basic considerations used by the Committee in arriving at their decisions are summarized.

In the design of equipment not covered by Codes, the design stress values may be decided upon by the manufacturer and purchaser of the equipment and should be based on the best available data plus a knowledge of the expected life of the equipment as well as the operating conditions and the possible hazard to personnel. Rules generally followed are:—

(1) Up to 750° or 850°F. (399° or 454°C.), 25 per cent. of the short-time tensile strength and not exceeding 62½ per cent. of the yield strength.

(2) Above 900°F. (482°C.), 100 per cent. of the stress to produce a second-stage creep rate of 0·01 per cent. in 1000 hours, or 80 per cent. of the stress to produce rupture in 100,000 hours, whichever is lower.

Revised stress values recently approved by the A.S.M.E. Boiler Code Committee for nickel-containing steels are shown in the Table below and those on pp. 76 and 77.

Maximum Allowable Stress Values in Tension for Nickel Steel Plates* p.s.i.

Material	Specification No.	Grade	Spec. Min. Tensile Strength	For Metal Temperatures not exceeding							
				–20° to 650°F. (–28·9° to 343°C.)	700°F. (371°C.)	750°F. (399°C.)	800°F. (427°C.)	850°F. (454°C.)	900°F. (482°C.)	950°F. (510°C.)	1000°F. (538°C.)
Nickel steel plates											
2 Ni-3½ Ni ..	SA-203	A, D	65,000	16,250	15,500	13,850	11,400	8,950	6,500	4,500	2,500
2 Ni-3½ Ni ..	SA-203	B, E	70,000	17,500	16,600	14,750	12,000	9,250	6,500	4,500	2,500
2 Ni-3½ Ni ..	SA-203	C	75,000	18,750	17,700	15,650	12,600	9,550	6,500	4,500	2,500

* Boiler Construction Code Table UG-23 (Boiler Construction Code—1950 Edition and subsequent revisions).

Maximum Allowable Stress Values for High-Alloy Plate Materials* p.s.i.

(see abstract p. 75)

Alloy Material	18-8 (Cr-Ni)	18-8 (Cr-Ni)	18-8 Mo (Cr-Ni-Mo)	18-8 Ti (Cr-Ni-Ti)	18-8 Cb (Cr-Ni-Cb)	25-12 (Cr-Ni)
A.I.S.I. Type	304	304	316	321	347	309
Specification No... ..	SA 167/SA 240	SA 167/SA 240	SA 167/SA 240	SA 167/SA 240	SA 167/SA 240	SA 167
Grade	3 S	3 S	11 M	5 T	6 C	8
Notes	(1)	—	—	—	—	—
Spec. Min. Tensile Strength	75,000	75,000	75,000	75,000	75,000	75,000
For Metal Temperatures not exceeding:—						
−20° to 100°F. (−29° to 37·8°C.)	18,750	18,750	18,750	18,750	18,750	18,750
200°F. (93°C.) ..	17,000	16,650	18,750	18,750	18,750	18,750
300°F. (149°C.) ..	16,000	15,000	17,900	17,000	17,000	17,300
400°F. (204°C.) ..	15,450	13,650	17,500	15,800	15,800	16,700
500°F. (260°C.) ..	15,100	12,500	17,200	15,200	15,200	16,600
600°F. (315°C.) ..	14,900	11,600	17,100	14,900	14,900	16,500
650°F. (343°C.) ..	14,850	11,200	17,050	14,850	14,850	16,450
700°F. (371°C.) ..	14,800	10,800	17,000	14,800	14,800	16,400
750°F. (399°C.) ..	14,700	10,400	16,900	14,700	14,700	16,200
800°F. (427°C.) ..	14,550	10,000	16,750	14,550	14,550	15,700
850°F. (454°C.) ..	14,300	9,700	16,500	14,300	14,300	14,900
900°F. (482°C.) ..	14,000	9,400	16,000	14,100	14,100	13,800
950°F. (510°C.) ..	13,400	9,100	15,100	13,850	13,850	12,500
1000°F. (538°C.) ..	12,500	8,800	14,000	13,500	13,500	10,500
1050°F. (566°C.) ..	10,000	8,500	12,200	13,100	13,100	8,500
1100°F. (593°C.) ..	7,500	7,500	10,400	12,500	12,500	6,500
1150°F. (620°C.) ..	5,750	5,750	8,500	8,000	8,000	5,000
1200°F. (648°C.) ..	4,500	4,500	6,800	5,000	5,000	3,800
1250°F. (675°C.) ..	3,250	3,250	5,300	3,600	3,600	2,900
1300°F. (704°C.) ..	2,450	2,450	4,000	2,700	2,700	2,300
1350°F. (734°C.) ..	1,800	1,800	3,000	2,000	2,000	1,750
1400°F. (760°C.) ..	1,400	1,400	2,350	1,550	1,550	1,300
1450°F. (788°C.) ..	1,000	1,000	1,850	1,200	1,200	900
1500°F. (815°C.) ..	750	750	1,500	1,000	1,000	750

* Boiler Construction Code Table UNA-23, prepared by Subcommittee on Stress Allowances for Ferrous Materials of the Subcommittee on Materials of the A.S.M.E. Boiler Code Committee.

† Tentative, not yet approved by Boiler Code Committee.

(1) These stresses are permitted when distortion can be allowed without endangering the safety of the structure.

(2) These stress values at temperatures of 1050°F. and above should be used only when assurance is provided that the steel has a predominant grain size not finer than A.S.T.M. No. 6.

(3) These stress values shall be considered basic values to be used when no effort is made to control or check the grain size of the steel.

Maximum Allowable Stress Values for High-Alloy Plate Materials* p.s.i.

(*see abstract p. 75*)

Alloy Material	25-20 (Cr-Ni)	25-20 (Cr-Ni)	—	—	—	—	—
A.I.S.I. Type	310	310	304L†	304L†	316L†	316L†	317L†
Specification No. ..	SA 167	SA 167	—	—	—	—	—
Grade	10	10	—	—	—	—	—
Notes	(2)	(3)	(1)	—	(1)	—	—
Spec. Min. Tensile Strength	75,000	75,000	70,000	70,000	70,000	70,000	70,000
For Metal Temperatures not exceeding:—							
−20° to100°F. (−29° to 37·8°C.)	18,750	18,750	17,500	17,500	17,500	17,500	
200°F. (93°C.) ..	18,750	18,750	17,000	17,000	17,500	17,500	
300°F. (149°C.) ..	18,500	18,500	16,000	13,400	15,800	14,500	
400°F. (204°C.) ..	18,200	18,200	15,000	11,000	14,750	12,000	
500°F. (260°C.) ..	17,700	17,700	14,000	9,700	14,000	11,000	
600°F. (315°C.) ..	17,200	17,200	13,000	9,000	13,600	10,150	
650°F. (343°C.) ..	16,900	16,900	12,500	8,750	13,450	9,800	
700°F. (371°C.) ..	16,600	16,800	12,000	8,500	13,250	9,450	
750°F. (399°C.) ..	16,250	16,250	11,500	8,300	13,000	9,100	
800°F. (427°C.) ..	15,700	15,700	11,000	8,100	12,700	8,800	
850°F. (454°C.) ..	14,900	14,900	—	—	—	—	—
900°F. (482°C.) ..	13,800	13,800	—	—	—	—	—
950°F. (510°C.) ..	12,500	12,500	—	—	—	—	—
1000°F. (538°C.) ..	11,000	11,000	—	—	—	—	—
1050°F. (566°C.) ..	9,750	7,100	—	—	—	—	—
1100°F. (593°C.) ..	8,500	5,000	—	—	—	—	—
1150°F. (620°C.) ..	7,250	3,600	—	—	—	—	—
1200°F. (648°C.) ..	6,000	2,500	—	—	—	—	—
1250°F. (675°C.) ..	4,750	1,450	—	—	—	—	—
1300°F. (704°C.) ..	3,500	750	—	—	—	—	—
1350°F.(734°C.) ..	2,350	450	—	—	—	—	—
1400°F. (760°C.) ..	1,600	350	—	—	—	—	—
1450°F. (788°C.) ..	1,100	250	—	—	—	—	—
1500°F. (815°C.) ..	750	200	—	—	—	—	—

Same as 316L

* Boiler Construction Code Table UNA-23, prepared by Subcommittee on Stress Allowances for Ferrous Materials of the Subcommittee on Materials of the A.S.M.E. Boiler Code Committee.

† Tentative, not yet approved by Boiler Code Committee.

(1) These stresses are permitted when distortion can be allowed without endangering the safety of the structure.

(2) These stress values at temperatures of 1050°F. and above should be used only when assurance is provided that the steel has a predominant grain size not finer than A.S.T.M. No. 6.

(3) These stress values shall be considered basic values to be used when no effort is made to control or check the grain size of the steel.

Nickel-containing Ceramels

W. SEITH and H. SCHMEKEN: 'Sintered Materials made from Metallic and Non-Metallic Powders.' *Heraeus Festschrift*, 1951, pp. 218-42.

The paper reports a study of the properties of sintered products containing alumina with iron, nickel, or molybdenum carbide. Determinations were made of density, tensile strength, and electrical and thermal conductivities, and the relations and interactions of the respective constituents were studied.

It was observed that a liquid phase occurs in the alumina-iron and the alumina-nickel systems sintered at 1850°-1900°C. Investigation of the range of miscibility within which sintering can be effected showed that for iron the maximum content for production of the ceramic-metallic mixtures is 59 per cent., and for nickel 55 per cent., both by weight. In the alumina-molybdenum carbide system, however, sintering was obtained in all proportions, since at temperatures up to 1900°C. no liquid phase occurs.

Nickel-containing Materials in the Glass-Making Industry

A. DAMMER: 'Ferrous Alloys for Production of Glass.' *Werkstoffe und Korrosion*, 1951, vol. 2, Nov., pp. 409-14.

A review of the factors requiring consideration in selecting materials for equipment used in glass-production and -forming. Discussion of the influence of temperature, stress, attack by furnace gases, and resistance to the alkaline media emanating from the glass, as affecting choice of materials used for forming tools, rolls, etc. The general popularity of austenitic heat-resisting steels and high-nickel nickel-chromium-base alloys is emphasized. Consideration is given to substitute materials of lower alloy content which may be suitable, in some cases, to replace the high-nickel types.

Properties of Nimonic Alloys: Tabular Summary

'Properties of Nimonic Alloys.' *Metal Progress*, 1951, vol. 60, Dec., p. 80B.

Summary data on composition, heat-treatment, physical properties and high-temperature creep characteristics of the range of Nimonic alloys. Attention is directed to D.T.D. specifications 725, 736 and 747, which cover, respectively, Nimonic 80, 80A and 90.

Gas-Turbine Locomotive: Use of Nickel-containing Materials

'British-Built Gas-Turbine Locomotive.' *Railway Gazette*, 1952, vol. 96, Feb. 1, pp. 125-30.

A detailed description, with many drawings and photographs, of British Railways second gas-turbine locomotive, No. 18100, which will shortly be placed in service on the Western Region.

The prime mover is a simple open-cycle gas turbine, without heat exchanger, and the cycle of compression, heating, and expansion of the air is carried out in a compressor, combustion chamber and turbine arranged in line and built into a straight-through single unit (illustrated). The compressor-cylinder is of malleable iron and the rotor is a forged-steel drum. Moving blades are machined from stainless-steel bar, and the fixed blades are rolled from a similar material. In the turbine the cylinder is of heat-resisting steel and the rotor is an austenitic nickel-chromium steel forging. The first stage of the fixed blading is in a Nimonic alloy, the second and third stages are of high-alloy nickel-chromium steel, and the fourth and fifth of a molybdenum steel. A Nimonic alloy is also used for both the first and second stages of the moving blades, the third stage is of austenitic nickel-chromium steel and the fourth and fifth are of molybdenum steel. Both the outer casing and the inner primary chamber of the flame tubes are constructed from a heat-resisting nickel-chromium steel.

Full particulars are given of the locomotive, as well as of the prime mover, and a graph shows typical performance in hauling an 18-coach train of 650 tons weight.

Melting Practice for Production of Extra-Low-Carbon Stainless Steel

W. CRAFTS and H. P. RASSBACH: 'Melting Low-Carbon Stainless Steel.' *Jnl. of Metals*, 1952, vol. 4, Jan., pp. 20-5.

This paper, presented at the A.I.M.E. Electric Furnace Steel Conference, is based on practice in the plant of Union Carbide and Carbon Corporation, who have developed stainless steel of the carbon 0·03 max. type on a commercial scale. The significance of the low-carbon product is demonstrated by an introductory graph showing the influence of carbon on the nitric-acid corrosion-resistance of 18-8 chromium-nickel steel after sensitizing for 2 hours at 1200°F. (648°C.).

The work done to date has determined, with sufficient accuracy for commercial production, the slag and metal relationships and other conditions required for melting of low-carbon stainless steels, and although it is admitted that some aspects of the subject still call for closer study, research and practical experience already available permit the following summary:—

'Decarburization with oxygen will oxidize the metal to a greater degree as the carbon is lowered and to a lesser degree as the temperature is raised. Under conditions resulting in a fluid slag, the total amount of iron, chromium, and manganese oxidized is not dependent on the chromium content of the charge, but the ratio of iron oxide to chromium oxide changes. Except at relatively high temperatures, high concentrations of chromium in the charge result in viscous slags that greatly increase the difficulty of decarburizing to very low levels. To avoid large slag volumes and excessive metal losses, it appears desirable in making 0·03 per cent. max. carbon stainless steel to oxidize at a high temperature and adjust the chromium content of the charge so that the oxidizing slag is relatively small in volume and is fluid at very low carbon contents.

'After decarburization to a very low carbon level, carbon pickup during subsequent working of the heat is a serious problem, especially in the basic-lined

furnaces. Carbon from the electrodes tends to dissolve in basic slag and transfers indirectly to the metal. The less basic slags dissolve less carbon and experimental steels made under low-basicity slags have shown little carbon creep. Under commercial conditions, the use of low-basicity slags facilitates the control of carbon in making 0·03 per cent. max. carbon stainless steel in basic-lined furnaces.

'Basicity is a primary factor in the reduction of the oxidizing slag, a high degree of basicity being essential to high chromium recovery. Further, in addition to carbon pickup in very low carbon heats, the slag volume is so large as to constitute a serious operating problem that is materially aggravated by the lime additions required to attain a high basicity. In higher-carbon stainless steels, decarburization to a level of 0·05 per cent. carbon or higher results in the formation of a relatively smaller slag volume, presenting no abnormal reduction problems. If the reduction slag is highly basic, a high recovery of chromium is realized and a high chromium charge may be used more effectively. Thus, the overall utilization of revert stainless steel scrap appears to be facilitated by the use of a higher proportion in the higher-carbon grades.'

Appreciation of the problems involved in manufacture of the very-low-carbon grades of stainless steel led to research on improved alloying materials, and to development of a new ferrochromium alloy characterized by very low carbon content and the presence of about 5 per cent. each of silicon and silica. Method of using the addition alloy is described; it can be employed effectively for melting in basic-chromite- and acid-lined furnaces. The carbon content is so low that in most instances the use of the new alloy tends to lower rather than raise the carbon content of the bath, and its solubility minimizes the danger of carbon pick-up, by shortening the alloying period: in large heats complete solution may be effected in about one hour, as compared with two to three hours required for solution of a similar addition of regular ferrochromium.

Effective Utilization of Stainless-Steel Scrap

G. C. CLOSE: 'Stainless Steel Foundry Conserves Critical Alloys.' *Steel*, 1951, vol. 129, Dec. 24, pp. 58-9.

This note is based on developments at Solar Aircraft Company, San Diego, California, in the use of scrap of stabilized 18-8 and high-temperature alloys for production of castings, thus conserving much strategic material.

Solar Aircraft first set up an experimental foundry, to explore the possibilities of commercial operation of such a scheme: as a result of their initial work the foundry is now producing 44,000 pounds of high-temperature alloy castings per month, and increase to 70,000 pounds per month is planned for the near future. Over 75 per cent. of the total charge melted has consisted of scrap from other departments in the plant, largely 18-8 and Inconel sheet from the cutting and trimming departments.

Solar Aircraft also claim to be working out successful techniques for casting titanium-stabilized stainless steels, providing a product which meets specification requirements for titanium : carbon ratio, and has an oxide-free surface and sub-surface area. Examples of components now being produced as titanium-stabilized austenitic steel castings include the fuel manifold for a jet engine, inner and outer cones of the J-34 turbojet, tailpipe flange rings for the North-American F-86, and flanges and selector valves of the B-36 bomber's exhaust system. All these parts were formerly made from forgings, but an experimental exhaust system incorporating cast parts proved to be dimensionally more stable than one in which corresponding forged parts were embodied. Changes in specifications to permit use of castings have been approved by the U.S. Armed Services.

Research on improved methods of casting is being actively continued, and various innovations have been introduced into the foundry procedure: for example, spraying of moulds and cores with a special wash, which allows higher pouring temperatures, resulting in better thin-walled castings and castings of complex design. Research investigations have also led to modification of the conventional sprue system of casting, and to use of a system of gates and risers which ensures increasingly better castings, and progressively fewer rejections for hot tears, shrinkage cavities, and sand inclusions.

Production of Stainless-Steel Pickling Baskets from Scrap

'Pickling Baskets made from Stainless Steel Scrap.' *Steel*, 1951, vol. 129, Dec. 31, p. 60.

Stainless-steel scrap arising in production of exhaust port flanges for aircraft is being successfully used to make pickling baskets which give much improved service in the molten salt mixtures and the hot and cold acid solutions used in pickling systems.

The pickling baskets were formerly made from wood, dowelled together with wooden pegs. Much timber was required and the basket had to be weighted with lead to secure complete immersion in the baths. Because the lead was rapidly attacked by the acids it was necessary to cover it with protective coatings: moreover, the use of wood was impossible in high-temperature molten salt baths, due to danger of ignition.

Scrap strip in the shops is straightened, cut to length and arc-welded to form the metal baskets, and, from the first, trials were eminently successful. The new baskets give a service life of three months, by comparison with ten days for wooden baskets. They are designed with easily removable bottoms, and construction is such as to ensure maximum drainage, so that no salts or acids are dragged out of the baths. The baskets carry up to 1,000 lb. of parts.

Preferred Orientation in Austenitic Nickel-Chromium and Ferritic Steel Castings

J. D. LAVENDER and J. I. MORLEY: 'Preferred Grain Orientation in Steel Castings.' *Jnl. Iron and Steel Inst.*, 1952, vol. 170, Jan., pp. 26-8.

Following observations of preferred orientation in castings of high-alloy nickel-chromium steels which are essentially austenitic at room temperature, an

C %	Si %	Mn %	Cr %	Ni %	Mo %	W %	V %	Fe %	N %
0·21	1·85	0·70	25·20	11·70	—	3·20	—	bal.	—
0·028	0·17	0·66	21·20	0·13	—	—	—	„	0·010
0·50	0·66	0·84	1·43	0·21	0·43	—	0·28	„	—
0·71	0·14	1·98	—	—	—	—	—	„	—
0·15	0·05	0·14	tr.	0·05	0·03	—	—	„	—

investigation was made of the nature of the preferred orientation in high-alloy steels which retain primary ferrite at room temperature and in some low-alloy steels in which during cooling a transformation occurs, from high-temperature austenite to low-temperature ferrite. This paper reports the observations made. The steels used were of the compositions shown above.

The results lead to the following conclusions:—

'The columnar grains in highly-alloyed steel castings have a preferred crystallographic orientation such that a (100) direction lies perpendicular to the mould wall from which the crystals have grown. This holds irrespective of the nature of the primary solidification, i.e., whether face-centred-cubic austenite or body-centred-cubic ferrite. The orientation is not disturbed by the transformation of primary delta ferrite to austenite, which occurs in certain steels at very high temperature during cooling. It is found, however, that the reverse transformation from primary austenite to ferrite, which occurs at lower temperatures, 600°C. and below, in steels of lower alloy content, including mild steel, appears to eliminate the preferred orientation of the columnar grains. Thus, castings of the plain carbon or low-alloyed steels are not subject to the elastic anisotropy of the outer columnar regions which is a feature of certain cast stainless steels.'

Continuous Rolling of Stainless Steel

'Extension of Continuous Rolling.' *Times Rev. of Industry*, 1952, Jan., p. 38.

This brief note comments on the significance of the stainless-steel rolling mill being built at Shepcote Lane, Sheffield, by Firth-Vickers Stainless Steels, Ltd., and the United Steel Companies. The development is indicative of the general policy of the steel industry in development of continuous-rolling methods as an aid to increasingly economical use of steel, combined with improved quality in the product. In the case of the continuous strip mill it is considered that the improvement is so great that the material resulting from it may be described as almost a new product.

Pickling and Etching of Stainless-Steel Sheet

H. E. ZENTLER-GORDON: 'Basic Principles of the Pickling and Etching of Steels and their Application to the Production of Stainless-Steel Sheet.' *Sheet Metal Industries*, 1952, vol. 29, Jan., pp. 5-10, 16.

The general aim of pickling and etching treatments for steels is outlined, and some notes are given on the types of solution most generally used: sulphuric acid and hydrochloric acid. The nature of their respective actions is indicated and the types of inhibitors which may be used to minimize attack on the metal are briefly described (organic, cation, and electrolytic inhibitors). The advantages of electrolytic methods for pickling are noted, with reference to typical processes.

It is pointed out that the scales produced on alloy steels differ from those found on carbon steels, necessitating different treatments for their removal. Typical chemical pickling solutions for stainless steel are given as

(1) Hydrochloric acid (d. 1.18) .. .. 42·5%
Nitric acid (d. 1·42) 5%
Water .. .. to 100%

(2) Hydrofluoric acid (52%) 20%
Nitric acid (1·14) 4%
Water .. .. to 100%

Solution 2 is used at 130°-150°F. (54°-65°C.), and in cases where the scale is particularly adherent it may be preceded by a dip in a solution containing 8 per cent. sulphuric acid and 4 per cent. (d. 1·16) hydrochloric acid, used at 140°-160F. (60°-70°C.).

(3) Ferric sulphate 8–12%
Hydrofluoric acid (52%) 3–4%
Water .. .. to 100%

This solution may be used at 150°-200°F. (70°-95°C.).

Except when electrolytic processes are used, the work must be given a preliminary cleaning, to remove adsorbed films of oil and grease which would inhibit action of the acids on the scale.

The writer gives some brief notes on the type of equipment used for pickling, and adds a warning on conditions which may give rise to hydrogen embrittlement in pickling.

In etching, for removal of surface defects and production of a clean and smooth surface for subsequent working, or as a treatment prior to electropolishing or other finishing process, the principal requirement is for a controlled rate of dissolution of the surface layers. The anodic etch most commonly used as a preliminary to electroplating or electropolishing of steel is a sulphuric-acid solution, varying from 10 to 70 per cent. concentration, to which chromic acid or potassium or sodium dichromate is sometimes added. A typical bath contains 60 per cent. sulphuric acid (d. 1·84) with 2 per cent. potassium dichromate. Such solutions are used at room temperature, at a current density of 100-200 amp./sq. ft. at 6 volt, treatment being for ½ to 2 minutes.

It has been found, during a study of electropolishing

methods, that much-improved surface can be secured in the finished product by a modification of the milling process used after initial rolling on the blooming mills. Electrolytic treatment has been found to give much better results than the normal milling technique, and trials have indicated the possibility of either entire elimination of the milling operation or of considerably reducing it. From the points of view of both economy and quality, results favour the electrolytic method of treatment. The cleaning bath used contains phosphoric acid as its main constituent, and is more dilute than most solutions employed in electrolytic cleaning; it also contains addition agents, sulphate and chlorides. Operation is at current densities of 30-150 amp./sq. ft. and 50°-70°C., the time of treatment being 10-20 minutes. The equipment used is of the type commonly employed for electroplating. In addition to the other advantages mentioned, it has been found that stainless steel processed by this electrolytic method has better drawing properties than that treated by conventional milling methods. It is stated that the working of stainless steels by the method recommended should effect a saving of about £5 per ton, together with production of sheet of improved quality.

U.S. Steel Specifications

See abstract on p. 70.

Influence of Nickel on Stability of Structure in Austenitic Nickel-Chromium Steels

P. BASTIEN and J. DEDIEU: 'The Position of the Ar''' Point in Stainless Nickel-Chromium-Steels and its Displacement by Cold Work.' *Métaux*, 1951, No. 315, Nov., pp. 423-6.

The work reported is an extension of earlier investigations for which some results were published in 1951: see *Nickel Bulletin*, 1951, vol. 24, No. 4, p. 88. Dilatometric and magnetic methods of measurement were used to study a range of steels containing chromium 18 per cent., with nickel varying from 4·25 to 11·35 per cent.

For steels heated at 870°C. for 24 hours and cooled at the rate of 300°C. per hour, the Ar''' point was lowered by about 50°C. for each additional 1 per cent. of nickel. Diagrams illustrate the marked rise in the temperature of the Ar''' point caused by cold-working of steels containing 8, 10 and 12 per cent. of nickel, and demonstrate variation in stability in two steels of closely related composition.

Sub-Zero Impact Properties of Stainless Nickel-Chromium and High-Nickel Steels

T. N. ARMSTRONG and A. J. MILLER: 'Impact Properties of Stainless Steel and 9 per cent. Nickel Steel after Exposure under Stress to Liquid Nitrogen.'* *Reprint from A.S.T.M. Bull.*, 1951, No. 177, Oct., pp. 35-6. *Issued by International Nickel Co., Inc.*, 1951; 2 pp.

For abstract see *Nickel Bulletin*, 1952, vol. 25, No. 1, pp. 25-6.

* *We shall be pleased to supply a free copy of this publication.*

Sodium Hydroxide as Inhibitor of Pitting in Austenitic Nickel-Chromium Steel

J. W. MATTHEWS and H. H. UHLIG: 'Sodium Hydroxide as Inhibitor of Pitting in 18-8 Stainless Steel." *Corrosion*, 1951, vol. 7, Dec., pp. 419-21; disc., pp. 421-2.

Following observations which indicated that sodium hydroxide exerted an inhibiting influence on the pitting of stainless steels in solutions containing chloride ions, the authors made a systematic investigation of the quantitative effect of alkali additions to sodium-chloride solutions, over a range of alkali concentrations.

An aerated 4 per cent. sodium chloride solution was used, at 90°C., as the basis corrodent, these conditions having been found to give the highest pitting rate in 18-8 (*Ind. Engg. Chem.*, 1941, vol. 33, p. 875). A 24-hour period was adopted as an accelerated test. The steel used (Type 304) contained chromium 18·6, nickel 8·5, carbon 0·06, per cent. Corrosion-test conditions and apparatus used are described and illustrated.

Additions of sodium hydroxide were varied up to 80 g. sodium hydroxide per litre of 4 per cent. sodium chloride. The results of the tests showed that a minimum of 8 g./L. (0·8 per cent.) sodium hydroxide inhibits pitting. At room temperature sodium hydroxide also suppresses pitting in brines.

Long-time tests (14 months) of 18-8 in 4 per cent. sodium chloride solutions containing various proportions of sodium hydroxide confirmed the conclusions drawn from the laboratory results.

The pitting mechanism results from galvanic action between a major surface of passive metal, acting as cathode, and a small active area of metal, acting as anode (the pit). Potential measurements show that sodium hydroxide depresses the noble potential of passive 18-8, thus diminishing the operating potential of the passive-active cell. In addition, the fast-moving hydroxyl ion reacts with any passivity-destroying corrosion products such as $FeCl_2$ at the anode, thereby stifling the chain reactions which initiate pitting.

Resistance of Nickel-containing Materials to Organic Acids and Related Compounds

H. O. TEEPLE: 'Corrosion by Some Organic Acids and Related Compounds.' *Corrosion*, 1952, vol. 8, Jan., pp. 14-27; disc., pp. 27-8.

The paper consists of a review of available data on resistance of ferrous and non-ferrous metals and alloys to corrosion by organic acids, particularly those of the lower aliphatic series. The conditions covered are those arising in production or use of the corrodents considered: the information given is based on both laboratory and large-scale tests.

The first part of the article is classified into sections dealing with behaviour in contact with the essentially pure acids (formic, acetic, butyric), mixtures of the acids with other compounds, and various anhydrides. Later sections cover resistance to aldehydes, ketones, alcohols, and esters. The metals and alloys discussed in the respective sections represent a wide range of

composition, including nickel, Monel, Inconel, many types of copper-base alloy, cast irons (including Ni-Resist), chromium and nickel-chromium stainless steels, Hastelloy alloys, aluminium-base materials, and a number of proprietary corrosion-resisting alloys.

The information given in the paper is supplemented by an annotated *bibliography* of literature relating to corrosion of metals and alloys by organic acids. The data are presented in tabular ready-reference form, and practical recommendations are made on the materials best suited for use under certain corrosive conditions.

Complex Nickel-Chromium-Iron Alloys Resistant to Sulphuric-Acid Sludge

E. G. HOLMBERG: 'Aloyco Experimental Alloys in Refinery Sulphuric-Acid Sludge.' *Paper to Amer. Petroleum Inst. Sub-Committee on Corrosion, Los Angeles, California,* Nov. 11, 1950; 7 pp. tables and figures.

Aloyco 20, a complex nickel-chromium-iron alloy (see table below) has been successfully used for many years in handling various concentrations of refinery sulphuric-acid sludge, but under certain conditions of temperature, acid concentration, velocity, etc., its behaviour has not been entirely satisfactory. Although alloys of the Hastelloy B or D types are resistant to such conditions, their cost cannot in all cases be justified. The Alloy Steel Products Company of New Jersey therefore carried out a series of tests in which corrosion resistance, in refinery sulphuric-acid sludge, was studied on a number of alloys modified from the basic composition of Aloyco 20, and on various other corrosion-resisting materials, including Monel, 70-30 cupro-nickel, Ampco 18, chemical lead. This paper reports the results.

The data presented relate to five different plant exposures, representing variation in sludge composition, temperature, and time of exposure. The general conclusion reached is that Aloyco 35 (see table) offers satisfactory resistance to a number of sulphuric-acid sludge conditions in which the No. 20 alloy is corroded at rates in excess of the limit considered permissible for satisfactory life of equipment. An alloy of the Aloyco 37 composition also showed good behaviour in some of the tests. Monel, cupro-nickel and brass, although giving good general resistance to corrosion, are not recommended, due to susceptibility to localized attack.

Materials of Construction for Amine Gas-Treating Plant

F. C. RIESENSELD and C. L. BLOHM: 'Corrosion Resistance of Alloys in Amine Gas-Treating Systems.' *A.S.M.E. Petroleum Mechanical Engineering Conference, Paper PET* 12; abstract in *Mechanical Engineering*, 1951, vol. 73, Nov., pp. 926-7.

On the basis of observations made over a period of three years in amine gas-treating plants, the following conclusions are drawn:—

'*Glycol-Amine Systems.* Heat-exchanger problems, which constitute the major problem, can be satisfactorily controlled by the use of aluminium alloy or 4-6 per cent. chromium-molybdenum steel in the manufacture of exchanger bundles. Carbon-steel reboiler bundles can be used economically, provided that correct operating conditions are maintained. Although carbon-steel stills have given satisfactory service, the incidence of some failure indicates that it is not an entirely suitable material for this service. Other materials are being investigated, and at present it is felt that a remedy for still corrosion can be provided by the use of aluminium or stainless-steel lining in the region of the still defined by the feed tray and the fourth tray below the feed, or by constructing the entire upper portion of the still of such alloys.

'*Aqueous Amine Systems.* In most of these systems carbon steel is a satisfactory material for heat-exchanger tubes, but in certain parts, where particularly corrosive conditions prevail, carbon steel and Type 304 nickel-chromium stainless steel have not given good performance. Although little experimental evidence is yet available, it is believed that Monel, Carpenter No. 20, and possibly type 316 stainless steel should prove useful. Reboiler corrosion, which in most aqueous amine plants constitutes the major corrosion problem, can be controlled by use of Monel, Carpenter 20 or Type 316 steel for reboiler bundles; Monel has shown the best results. In most cases carbon steel has performed reasonably well in aqueous-amine stills. Type 304 has been found satisfactory for stills operated over a prolonged period.'

Monel Petrol Tanks

See abstract on p. 63.

Bolts, Studs and Nuts for Use in the Petroleum Industry

See abstract on p. 71.

Alloy	C %	Cr %	Ni %	Mo %	Cu %	Mn %	Si %	Fe %
Aloyco 20 ..	0·07	20·00	29·00	2·50	4·00	0·75	1·00	Bal.
„ 35 ..	0·07	25·00	20·00	3·00	2·75	0·75	1·00	Bal.
„ 37 ..	0·07	25·00	20·00	3·00	2·75	0·75	3·00	Bal.
Hastelloy B .. (Aloyco N-2)	0·07	—	64·00	28·00	—	0·65	1·00	6·00
Hastelloy D ..	0·10	—	85·00	—	3·00	—	10·00	—

Nickel-containing Materials in the Meat-Packaging Industry

M. D. SANDERS, A. W. DE VOUT, P. BRADFORD and W. F. BOLLENS: 'Chemical Engineering in the Meat-Packaging Industry.' *Chemical Engineering Progress*, 1951, vol. 47, Sept., pp. 443-8.

This paper, prepared by members of the staff of Swift and Company, Chicago, comprises a condensed review of chemical-engineering operations involved in large-volume operations of the industry, and of equipment used in the respective stages. In some cases materials of construction are discussed, on the basis of working experience. Some notes on this aspect of the subject are given below:—

Special Operations

Rendering: Carbon steel is the universal material of construction: copper and its alloys are carefully avoided, due to acceleration of oxidation of fats by traces of copper.

Fat Splitting: Three processes are used: (1) Twitchell, (2) batch-autoclave, and (3) continuous. In (1) lead-lined equipment is used, in (2) carbon steel, in (3) stainless-clad or Inconel-lined.

Saponification: In the full-boiler process, which is the most important in terms of volume, the soap kettles are usually cylindrical vessels with cone bottoms, and, for the better grades of soap, are constructed of stainless steel in the upper section, to a point below the normal soap level, to prevent atmospheric as well as other forms of corrosion. Typical operations are diagrammatically illustrated.

Unit Operations

Gelatine Extraction: Aluminium or stainless-steel kettles are common; wooden vessels have also been used.

Hide-Glue Extraction: Extraction kettles are of wood or carbon steel. For production of *bone glue*, carbon-steel pressure tanks are employed.

Solvent Extraction: In various stages of this process stainless steel equipment is essential, especially in the decolorization equipment in which propane and the fat product are handled.

Evaporation: In the units employed for concentrating tank water, etc., cast-iron bodies with copper tubes are usual, but the copper tubes are relatively short-lived, and stainless steel is becoming increasingly popular. For gelatine evaporators aluminium, stainless steel and nickel are the materials most commonly used. For calandria-type evaporators handling glycerine-containing sweet water, special materials, such as stainless steel, are preferably used, in order to prevent corrosion from the action of fatty acids which may be present in the solutions.

Drying Operations: Although the procedure adopted is described, with details of design of equipment, but little reference is made to materials of construction used. Choice is presumably dictated by the nature of the material being dried. For drying of high-purity edible gelatine, aluminium, Inconel and nickel wire is used for the drying nets.

Filtration: Filtration equipment varies from relatively small pressure filters for clarification of liquid soap to large rotary filters for dewatering sludge from waste treatment. Cast-iron plate-and-frame filters are common for removal of bleaching clay and carbon from fats after the bleaching operation, and cast-iron presses are used for filtration of glycerine and treated spent soap lyes. Aluminium or stainless-steel presses are preferred for clarification of gelatine.

Distillation: Deodorization of fats, including lard, is carried out by steam-stripping under high vacuum. The vessels are of carbon steel. In distillation of glycerine carbon-steel stills are used for the partial-high-pressure process and the glycerine is subsequently condensed in copper-tubed partial condensers, to recover commercial grades.

Crystallization: In this process, which is applied particularly to fats, extensive use is made of stainless-steel equipment, to avoid corrosion from the fatty acids present. Nickel is also employed, e.g., for scrapers in chilling machines.

Comminution, Grinding and Screening: The variety of materials handled is so great that almost every type of mill is used. No reference is made to materials of construction.

Centrifuging: Stainless-steel separators are used in grease separators employed to lower the grease content of bone glue.

The authors emphasize that the description given is somewhat generalized and incomplete, but they express the hope that it may lead to more detailed treatment, in later papers, of some of the complex processes mentioned in their review.

Stainless-Steel Equipment in Synthetic Rubber Plant

'Stainless Steel Licks Corrosion, Boosts Synthetic Rubber Output.' *Iron Age*, 1951, vol. 168, Dec. 13, p. 130.

In the production of synthetic rubber, the wet crude product, resulting from a series of chemical reactions, is coagulated in an acid-brine bath, and the latex is then washed and filtered. The crumb so produced leaves the filter with about 30 per cent. of water still present, as well as some sulphuric acid and salt which are not removed by washing. Drier flights carry this material to ovens maintained at 175°F. (80°C.), and the conditions prevailing (high humidity+salt and acid) are highly corrosive. Black-iron drier flights formerly used were short lived, and, due to rusting and corrosion, contaminated the rubber product.

In the plant of United States Rubber Company (now being operated for the U.S. Office of Rubber Reserve), extensive modernization was recently carried out, including replacement of the black-iron drier flights by flights of Type 316 stainless nickel-chromium steel. The eight conveyors each consist of 173 hinged sections of 16-gauge sheet. It is reported that this change of material has entirely eliminated corrosion (and consequent contamination of the rubber) and, since the particles do not adhere to the stainless steel as they did to the black iron, the dried rubber is more easily removed from the conveyor. Both output and quality of the product have been improved by the change.

Iron-containing Cupro-Nickel Alloys: Constitution and Properties

See abstract on p. 63.

Copper in Stainless Steels

H. THIELSCH: 'Copper in Stainless Steels.' *Welding Research Council Bulletin Series No.* 9, Aug., 1951; 31 pp.

Report prepared under the auspices of the Literature Advisory Committee of the Welding Research Council.

The copper-bearing stainless steels represent particular types of steel in which the copper addition (generally about 1-5 per cent.) is made to increase resistance to certain forms of corrosive environment, to decrease the susceptibility of austenitic stainless steels to stress-corrosion cracking, and/or to confer age-hardening properties.

The copper-containing stainless steels may be divided into four major groups:—

(1) Martensitic or ferritic steels containing up to 30 per cent. chromium, 0-3 per cent. nickel, and up to about 1 per cent. copper. These materials are used primarily for corrosion-resisting purposes, e.g., in condenser tubes, in marine and other applications involving contact with sea water, and in food-handling equipment.

(2) Partially ferritic steels containing up to about 25 per cent. chromium, 3-10 per cent. nickel, and up to 4 per cent. copper. These steels, which are age-hardenable, are used at normal or intermediate elevated temperatures, e.g., in gears, cams, pinions, valve plugs and other parts requiring a combination of age-hardening capacity and high resistance to corrosion.

(3) Medium-nickel fully austenitic steels containing chromium 12-30, nickel 10-20, copper 2-4, per cent. Age-hardening steels of this type are used, at temperatures up to about 1500°F. (815°C.), for gas- and steam-turbine parts, superheaters, etc.

(4) High-nickel, fully austenitic stainless steels containing chromium 15-30, nickel 20-35, copper 2-5, per cent. are used primarily in applications in which the requirement is for resistance to solutions or slurries containing sulphuric, acetic, or phosphoric acid, caustic solutions, corrosive petroleum products, weak chlorides, etc., which would corrode copper-free stainless steels.

The physical properties and metallurgy of the copper-bearing stainless steels present certain phenomena which are not observed in the straight-chromium or nickel-chromium stainless steels, e.g., hot-shortness, and the formation of undesirable alloy phases in certain ranges of temperature. Such characteristics require close consideration in relation to a number of applications, and particularly in connexion with welding. The present review has been prepared to bring together the scattered data available on these various aspects: the compilation was especially designed to form a background to a study of welding of copper-bearing stainless steels, on which a report was recently published by the same author (see *Nickel Bulletin*, 1951, vol. 24, Nos. 9-10, pp. 216-17). The information presented, which is essentially of a reference character, does not permit of detailed abstraction, but its scope is shown below by means of a skeleton list of contents:

Introductory Notes on Corrosion-Resistance of Copper-containing Stainless Steels, General Effects of Copper, Effects of Copper in Castings, and Effect of Copper on Welding.

Phase Relationships and Physical Metallurgy.

Scaling-Resistance and Hot-Working Characteristics.

Stainless Steels containing

up to 3 per cent. Nickel.
3–10 „ „
10–20 „ „
over 20 „ „ with
(*a*) up to 15 per cent. chromium;
(*b*) over 15 per cent. chromium.

In each of these composition groups the author summarizes existing information on general characteristics, the influence of composition, structure, corrosion-resisting qualities, age-hardening characteristics, mechanical properties, hot-workability, and welding qualities. Consideration is also given to heat-treatment, and to complex nickel-chromium-copper-containing steels, e.g., those containing substantial percentages of manganese or molybdenum, or stabilizing elements.

Miscellaneous Copper-bearing Stainless Steels.

A list of compositions which have been the subject of patents is given: the steels cover a wide range of nickel content. Reference is also made to chromium-manganese steels containing additions of copper.

The review is supplemented by a *bibliography* of 166 references.

Monel for Ball Valve Seats

INSTN. WATER ENGINEERS: 'Review of Current Investigation No. 8. Research Group Report on Waterworks Fittings.' *Jnl. Instn. Water Engineers*, 1951, vol. 5, Nov., pp. 700-18.

The Research Group on Waterworks Fittings was formed in 1946 for the purpose of 'initiating, coordinating and recording results of research on waterworks fittings, materials of construction.' In view of the urgent and practical interest in prevention of wastage, it was decided to ask members of the Institution in charge of water undertakings what, in their experience, was the type of fitting which constituted the greatest source of waste, and what was the nature of the defect giving rise thereto, e.g., faulty construction, corrosion, faulty materials, etc. From the 80 replies received it was clear that the most common source of waste was the ordinary Portsmouth-type ball valve, and that the most common defect which might be easily remediable was erosion and/or corrosion of the seat. It was therefore decided that the initial work of the Research Group should be directed to finding a method of prolonging the useful life of ball-valve seats. This report describes the tests made and gives the conclusions drawn from the results.

Prototype seats were made from six different alloys: high-tensile brass, aluminium bronze, phosphor bronze, nickel silver, Monel, and commercial 60-40 brass. In order to evaluate the possible influence of

shape of seat, two forms in each material were tested: chamfered-face and rounded-face (illustrated), and the installations were operated with waters representative of the main sources of potable water in Great Britain, viz., sandstone-derived well waters, chalk-derived well waters, moorland waters, and waters from the lower reaches of rivers. Each type was used in the natural condition, and as-treated to contain a standardized amount of chlorine (0·15 p.p.m.). In all, 402 seats were tested, comprising over 60 of each of the alloys mentioned above.

Very full particulars are given in the report of the results obtained in the individual test runs: the performance of each specimen was assessed in accordance with the following order of merit: very good, good, fair, poor, and very poor (failure). The results are further broken down into classifications showing the effect of the presence of chlorine and of shape of valve seat. The report is well illustrated by photographs showing the condition of typical seats. The conclusions drawn are given below:—

'(1) As long as chlorination of waters continues to be almost standard practice, the use of brass as a material of construction for valve seats will lead to their fairly rapid corrosion-erosion, with consequent waste of water.

'(2) The addition of aluminium to 60-40 or two-phase brass improves its resistance to corrosion-erosion when used in waters with the small proportion of free chlorine commonly occurring in distributed potable waters. In unchlorinated waters, however, the addition of aluminium to that type of brass lessens its resistance to corrosion-erosion.

'(3) Of the six alloys tested, Monel proved the most resistant in all but five of seventeen series of tests in both unchlorinated and chlorinated waters. Of the five exceptions, in two cases Monel shared first place with phosphor bronze; in two others, the waters had a free CO_2 content of 35 p.p.m. and 57 p.p.m., respectively; in the fifth case, of four seats tested two were judged very good, one fair, and one poor. In view of the inconsistency of that result, as compared with the generally high level of results, some doubt must remain as to whether accidental circumstances did not prevail.

'The group therefore feels justified in concluding that, for valve seats in all waters apart from those possessing very unusual characteristics, such as a very high free CO_2 content, Monel will be the most satisfactory of the six alloys tested, from the point of view of resistance to corrosion-erosion. Recent international circumstances have influenced adversely the importation of metals, and it might be considered inopportune to suggest the use of alloys requiring constituents rather rarer than those already in common use for waterworks fittings. In research, however, it is necessary to take the long-term view .... Since the Group's recommendations relate to only a small, though important, component of a waterworks fitting, the substitution of a new alloy can have very little effect upon the metal-supply position, and that out of all proportion to the saving of water and maintenance work which it would be designed to achieve. No specific conclusion as to the most appropriate alloy for use in waters of an extraordinary composition as regards free CO_2 content and pH value, can be drawn from the tests.' Further tests, including additional materials, are recommended to settle this point.

In connexion with the suggested use of Monel for the valve seats, the Group draws attention to the usefulness, for this purpose, of the high-carbon free-machining grade of the alloy, which is particularly well adapted for handling in automatic screw machines. The carbon content of this grade, which is higher than that of standard Monel, does not impair the corrosion-erosion-resistance of the alloy. Monel in which free-machining properties are obtained by sulphur additions is not suitable for the purpose.

Identification Tests for Nickel-containing and Other Materials

See abstract on p. 58.

Welding of 35-15 Nickel-Chromium-Iron Castings

R. D. THOMAS: 'Welding of High-Alloy Castings.' *Welding Jnl.*, 1952, vol. 31, Jan., Suppl. pp. 27-32.

Discussions held by the Alloy Casting Institute a few years ago revealed the need, in foundry welding shops, of a standard test by which welding procedures, filler metals, and weldability of casting alloys could be evaluated. The High-Alloy Steel Committee of the Welding Research Council therefore initiated research designed to develop a suitable test method, and after two years of preliminary investigation established a slotted-groove test plate, described and illustrated in this paper.

Using material prepared from a single melt, four foundries co-operated in preparation of welds in the standard slotted-groove test plate. Choice of welding procedure was left to the individual foundries: it varied widely as to technique, choice of electrode, etc. Supplementing these tests, another series was made in which all foundries used a standard electrode. An account is given of the methods employed, typical welds are illustrated, and a detailed report is made of the characteristics of the welded joints produced in the respective shops.

General observations on the effects of welding variables are briefly summarized below:—

Continuous welding in the vertical position is not good practice, but layer welding in a groove inclined 45° appears to be a promising procedure. Such a method greatly reduces the degree of restraint, and consequently eliminates the weld-bead and crater cracks occurring in down-hand welds, without causing the fissure cracks apparent in continuous vertical welds. When welding in the flat position care must be taken to overcome root-bead and crater cracks.

Hot-fissure cracks occur readily in very-low-carbon weld metals, but evidence is conflicting with regard to behaviour at 0·15 per cent. carbon and above. With a given welding technique, hot tears are usually more frequent with the lower-carbon electrodes. Electrode compositions similar to those of the castings appear to be suitable, providing that there is a careful control of welding procedure.

A few short-time-tensile high-temperature tests on welded joints are reported; these show that in almost every case the strength of the weld is nearly equal to that of the base metal. In cases in which the welds contained no defects revealed by the pre-testing inspection of the specimens, failure occurred almost always in the weld metal. Conversely, fissures or other defects usually weakened the weld metal sufficiently to cause failure in the weld, but such failure occurred at strength levels approximating those of the base metal.

The Committee responsible for this research is extending the programme, in order to obtain further information on the effect of welding technique on soundness of the joints, and to make a study of the service properties of welds made by procedures proved to be optimum.

Silver-Brazing of Stainless Steels

J. P. EMMERICH: 'Hints for Silver-Brazing of Stainless Steel.' *Welding Jnl.*, 1952, vol. 31, Jan., pp. 50-3.

This is a well illustrated article, making practical recommendations on materials and technique. Tables I and II below show, respectively, the grouping of the stainless steels which may be joined by silver brazing, and the brazing alloys suitable for the respective grades of steel.

Major points of importance are:—

(1) Choice of correct combination of steel and brazing alloy (see tables).

(2) Correct heating of the part. It is recommended that a 3x or 4x excess acetylene flame be used, giving

Table I

Group A				Group B			Group C		
Martensitic Straight chromium Hardenable				Ferritic Straight-chromium Non-hardenable			Austenitic Chromium-nickel Non-hardenable		
Type		Scaling Temperature		Type	Scaling Temperature		Type	Scaling Temperature	
		°F.	°C.		°F.	°C.		°F.	°C.
403		1200	650	329	1600	870	302	1600	870
410		1250	675	406	1300	705	303	1600	870
414		1200	650	430	1300	705	304	1600	870
416		1250	675	430-F	1300	705	305	1600	870
420	Corrosion-			443	1600	870	309	2000	1095
420-F	resistance			446	1900	1035	310	2000	1095
440-A	impaired						316	1650	900
440-B	when heated						317	1600	870
440-C	to over						321	1600	870
440-F	700°F.:						347	1600	870
	370°C.								

Table II
Silver-Brazing Alloys

Composition				Flow Point		Colour	Recommended Use (see Table I)
Silver %	Copper %	Zinc %	Cadmium %	°F.	°C.		
50*	15·5	15·5	16	1270	686	Yellow	Group B, C
50	15·5	16·5	18	1175	635	Yellow	Group A, B, C
47	20	17·5	15·5	1240	670	Yellow	Group B, C
45	15	16	24	1145	618	Yellow	Group A, B, C
35	26	21	18	1295	702	Yellow	Group C and some Group B
34	27	18	21	1300	705	Yellow	Group C and some Group B

* Contains 2-3% nickel.

an acetylene feather three or four times the length of the inner cone.

(3) Correct sequence of operations:—
(1) Remove excess grease, oil or dirt from the part.
(2) Degrease and abrasion-clean the part immediately before fluxing and silver-brazing.
(3) Place the part in a penetrating cleaner to remove all traces of oil and grease.
(4) Apply flux generously.
(5) Heat with an excess acetylene flame.
(6) Apply silver alloy to the joint.
(7) Saturate the joint with heat without increasing the temperature of the part.
(8) Cool the part in air until the silver alloy has solidified, then quench in water.
(9) Remove the scale and any remaining flux.

Dissimilar-Metal Welded Joints made with Stainless-Steel Electrodes

H. THIELSCH: 'Stainless-Steel Weld Deposits on Mild and Alloy Steels.' *Welding Jnl.*, 1952, vol. 31, Jan., Suppl. pp. 37-64.

Report prepared under the aegis of the Literature Advisory Committee of the Welding Research Council.

Detailed review, supported by *bibliography* of 114 references, of published and unpublished information on dissimilar-metal joints made with austenitic nickel-chromium steel electrodes. The subject is dealt with in sections covering:

Nature of the Joint and Constitution of the Metal in the heat-affected zone of the base steel, the transition zone in the weld metal, and the diluted weld metal.

Mechanical Characteristics of Dissimilar-Metal Welded Joints (residual stresses, weld design, distortion and machinability).

Effects of Heat Treatment of Welded Joints (stress-relieving, hydrogen embrittlement, metallurgical changes, normalizing, pre-heat treatments).

Effects of Elevated-Temperature Exposure (carbon diffusion, and the effect, on it, of temperature of heat-treatment, metallurgical structure, chemical composition, time at temperature, and stress; effect of carbon diffusion on carbide precipitation; graphitization).

Failure in Dissimilar-Metal Joints (cracking of base and of weld metal, and other forms of defect or failure).

Hardenable Steels (use of austenitic electrodes on low-alloy, armour-plate and other hardenable steels; welding procedure for use on hardenable steels).

Welding of Austenitic and of Ferritic Stainless Steels with austenitic electrodes.

Corrosion-Resisting Properties of Dissimilar-Metal Weldments.

Applications of Dissimilar-Metal Joints.

Special Types of Joints: the Kelcaloy Joint.

Dissimilar-Metal Joints in Steel and Alloy Components used in Various Types of Equipment, e.g., railway and electrical equipment, gas turbines (high-alloy steels, and chromium-, cobalt- and nickel-base alloys).

On the basis of the information summarized, the author concludes that the following aspects of the subject call for further investigation: (1) advantages and disadvantages of pre- and post-welding heat-treatment; (2) dilution, with special reference to the effects of the various alloy elements; (3) buttering with 25-20 chromium-nickel-iron electrodes.

Knife-Line Intergranular Corrosion in Welded Nickel-Chromium Austenitic Steels

M. L. HOLZWORTH, F. H. BECK, and M. G. FONTANA: 'The Mechanism of Knife-Line Attack in Welded Type 347 Stainless Steel.' *Corrosion*, 1951, vol. 7, Dec., pp. 441-9.

In introducing the paper by a condensed summary of accepted views on intergranular corrosion in austenitic steels, and its prevention by addition of 'stabilizing' elements such as niobium and titanium, the authors draw attention to the fact that although numerous investigations have been made of the effects of minor constituents in these steels, little work has been reported on the solid solubility, at temperatures above 2000°F. (1093°C.), of niobium and titanium. It has been stated that at 1200°F. (649°C.) about 0·1 per cent. niobium is soluble in austenite for a Type 347 stainless steel containing 0·03 per cent. carbon, and that for a steel containing about 0·70 per cent. niobium all niobium carbides are in solution above approximately 2300°F. (1260°C.).

The present paper is concerned with an investigation of the occurrence of knife-line intergranular corrosion of welded Type 347 steel in contact with nitric acid. This form of attack occurs in a narrow band immediately adjacent to the dendritic zone of the weld, and differs from deterioration in welded Type 304 (unstabilized) steel occurring in the 'weld-decay zone' which is farther away from the actual weld. Typical examples of knife-line corrosion in nitric-acid containers are shown, and notes are added on observations made by other investigators.

The experimental study of the mechanism of the breakdown was done on steels of the composition shown in the Table below.

The conclusion arrived at from the detailed results reported is that knife-line attack occurs only under specific conditions, and that 'the mechanism is based on the solid solubility of niobium in 18-8 stainless steels at high temperatures, with consequent formation of grain-boundary chromium carbide during the sensitizing treatment.' Niobium is dissolved at very

Cr %	Ni %	C %	Nb %	Mn %	P %	S %	Si %
17·65	10·85	0·07	0·06				
17·37	9·95	0·085	0·91				
18·05	10·56	0·087	0·72				
17·15	10·36	0·07	0·97	1·48	0·018	0·015	0·61
18·69	11·03	0·03	0·38	1·40	0·022	0·005	0·51

high temperatures, and remains in solution when the steels are cooled at a fairly rapid rate. Substantial and practically complete solubility of niobium was observed in the range 2300°-2500°F. (1260°-1370°C.) for regular Type 347. Knife-line attack was observed in Type 347 steels in fuming nitric acid and in boiling 65 per cent. nitric acid (Huey test). Extra-low-carbon Type 347 appears to be practically immune from susceptibility to knife-line attack.

From the essentially practical point of view, the authors emphasize that knife-line attack may not occur under all conditions: particular combinations of welding, heat-treatment and corrosive media are essential for its occurrence. It is, however, a possibility which should not be overlooked in the fabrication of chemical-engineering parts.

Fused Metallized Coatings Coating Nickel: Naval Applications of Hard Facing

H. S. SAYRE: 'Development of Fused Metallized Coatings.' *Welding Jnl.*, 1952, vol. 31, Jan., pp. 35-9.

This article describes some development work done by the U.S. Naval Engineering Experiment Station, Annapolis, with particular reference to the use of hard facing of steel for propellers and improved protection of outboard propeller shafting.

Investigation of the possibility of hard facing for such purposes began, some years ago, with a basic study of the various methods for deposition of hard-facing or corrosion-resisting coatings: gas welding, electric-arc welding, and metallizing+re-melting. Following brief notes on the welding methods, the author of this paper gives a detailed account of the new fusing-metallizing process. In this procedure a controlled thickness of the selected overlay material is applied by metallizing, using a metal-spray gun. The coating is then re-melted (by oxyacetylene torch, controlled-atmosphere furnace heating, or induction heating), forming a homogeneous fused-metal overlay. The steps in the process, and the precautions to be observed, are described, and the appearance of typical metallized parts is illustrated.

Initial trials of the process were carried out by metallizing a steel propeller with phosphor bronze. The treated component gave good results under trial in Severn water, but cladding with phosphor bronze was found to entail certain disadvantages which would render the application difficult and impractical from a production standpoint.

In the continued search for a satisfactory protective-coating material many metals and alloys were tried, including nickel, brass, Monel, stainless steel and nickel-chromium-tungsten-containing alloys: none was found entirely suitable for the purpose. Highly successful results, have, however, been obtained by the use of an alloy containing chromium, nickel and boron. Results obtained with the composition first tried (nickel 65-75, chromium 13-20, boron 3-5, per cent.) were promising, but indicated the need for some change in coating composition. A modified mixture was therefore developed, comprising 40 parts of the original alloy and 60 parts nickel (by weight), with sufficient silicon to raise the silicon content of the final alloy to 5 per cent. Application of this alloy on a steel propeller, by controlled methods (details of which are given), produced crack-free coatings, and salt-water-immersion tests showed the overlay to be corrosion-resistant, giving full protection to the underlying steel. Further tests indicated that with such coatings it would be possible, in the event of repair being required, to grind off a local area, and re-fuse-metallize, without causing cracking which had been observed on repair of facings made from the original nickel-chromium-boron alloy. Practical evaluation of the method is planned in connexion with the rehabilitation of the damaged steel blades of an ice-breaker propeller.

The potential value of the process in saving copper now used in ships' propellers is urged. Its importance is also stressed in relation to use on propeller shafting, an application in which the deposition of the fused-metallized coating is facilitated by the shape of the component. The original nickel - chromium - boron coating can be applied to low-alloy steels without difficulty, but on high-carbon and alloy steels, such as 3½ per cent. nickel steel, the coating was found, in salt-water tests, to be subject to stress corrosion. This limitation was overcome by the use of the modified alloy described above: a coating of this material showed neither cracks nor corrosion after over 4 months' exposure in Severn water. The fusing-metallizing procedure is *not* suitable for use on shafting of tensile strengths higher than about 80,000 p.s.i. (36 tons per sq. in.).

Fused-metallized coatings are believed to have a very wide range of potential application, among which an important use is likely to be for maintenance of production tools and gauges. An example quoted in this paper relates to use on mandrels, in which chromium-plated tool steel had given a life of only about 75 operations. Mandrels faced by the new process are stated to show no signs of wear after 35,000 operations. The U.S. Bureau of Aeronautics is employing this method to increase the life of arrester hooks on carrier-based aircraft.

Determination of Niobium in Molybdenum-containing Stainless Steels

'New British Chemical Standards.'

The Bureau of Analysed Samples, Ltd., announces availability of No. 246, for niobium-molybdenum 18-8 chromium-nickel steel. This sample has been specially prepared for checking determination of niobium in stainless steels and for giving accurate estimations of carbon in low-carbon grades. It is also intended to be useful for checking determination of molybdenum in high-molybdenum stainless steels. The composition is given as: carbon 0·062, niobium 0·82, molybdenum 2·89, per cent.

Corrigenda

Nickel Bulletin, January, 1952 :

P. 19 Table I. For "Ch" at top of 10th column, please read "Cb."

Table II Col. 2. Delete minus sign before 7·4.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

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